

EARTH ORBITAL EXPERIMENT PROGRAM

AND

REQUIREMENTS STUDY

VOLUME 3

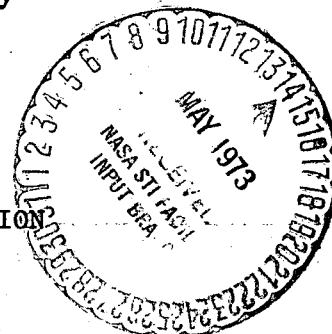
SPACE BIOLOGY

(APPENDICES A, B, C)

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for

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## FOREWORD

The information presented in this report summarizes three major steps toward production of a reference manual for planners of manned earth-orbital research activity. The reference manual will serve as one of the principal tools of a systems approach to experiment and mission planning based on an integrated consideration of candidate research programs and their attendant vehicle, mission, and technology development requirements.

The first major step toward preparation of the manual was the development of long-range goals and objectives suitable for NASA's activities during the 1970-1980 time period. This work was completed by NASA Headquarters with active center support and was published in September 1969 as a portion of a report for the President's Space Task Group entitled, "America's Next Decade in Space."

The second major step was a contractual study effort undertaken in September 1969 by McDonnell Douglas Astronautics Company-West with the TRW Systems Group, the IBM Federal Systems Division, and the RPC Corporation. The purpose of the study was to structure the NASA-developed goals and objectives into an orderly, system-oriented set of implementation requirements. The contractor examined, in depth, the orbital experiment program required to achieve the scientific, technological, and application objectives, and determined in a general way the capabilities required in future manned orbital programs to accommodate the defined experiments. Thus, the basic task of the contractor was to aid NASA in studying the useful and proper roles of manned and automated spacecraft by examining the implementation alternatives for NASA experiments.

The third major step presented in this document is the result of an integrated consideration of NASA's long-range goals and objectives, the system and mission requirements, and the alternative implementation plans. It will serve as a source of detailed information and methodology for use by NASA planners in development and justification of future programs.

## Management

Technical direction (fig. 1) of the contracted study effort is the responsibility of the Advanced Aerospace Studies Branch (AASB) of the Space Systems Division (SSD) at the Langley Research Center (LRC). Technical guidance is provided by the Earth Orbital Experiment Program Steering Group which reports through the Planning Steering Group (PSG) to the Associate Administrator. Technical coordination is also maintained with appropriate personnel at ARC, GSFC, MSC, and MSFC.

The membership of the Steering Group (fig. 2) comprises representatives of the working groups of the PSG under the chairmanship of Dr. R. G. Wilson, Director, Advanced Programs, OSSA. The NASA Study Management Team is headed by Mr. W. R. Hook of the AASB. Technical support is supplied by elements of the Langley Research Center as required.

The contractor's Study Team is headed by Dr. H. L. Wolbers, MDAC, and the Senior Management Review Council is chaired by Mr. C. J. Dorrenbacher, Vice President, Advanced Systems and Technology, MDAC.

# EARTH ORBITAL EXPERIMENT PROGRAM AND REQUIREMENTS STUDY

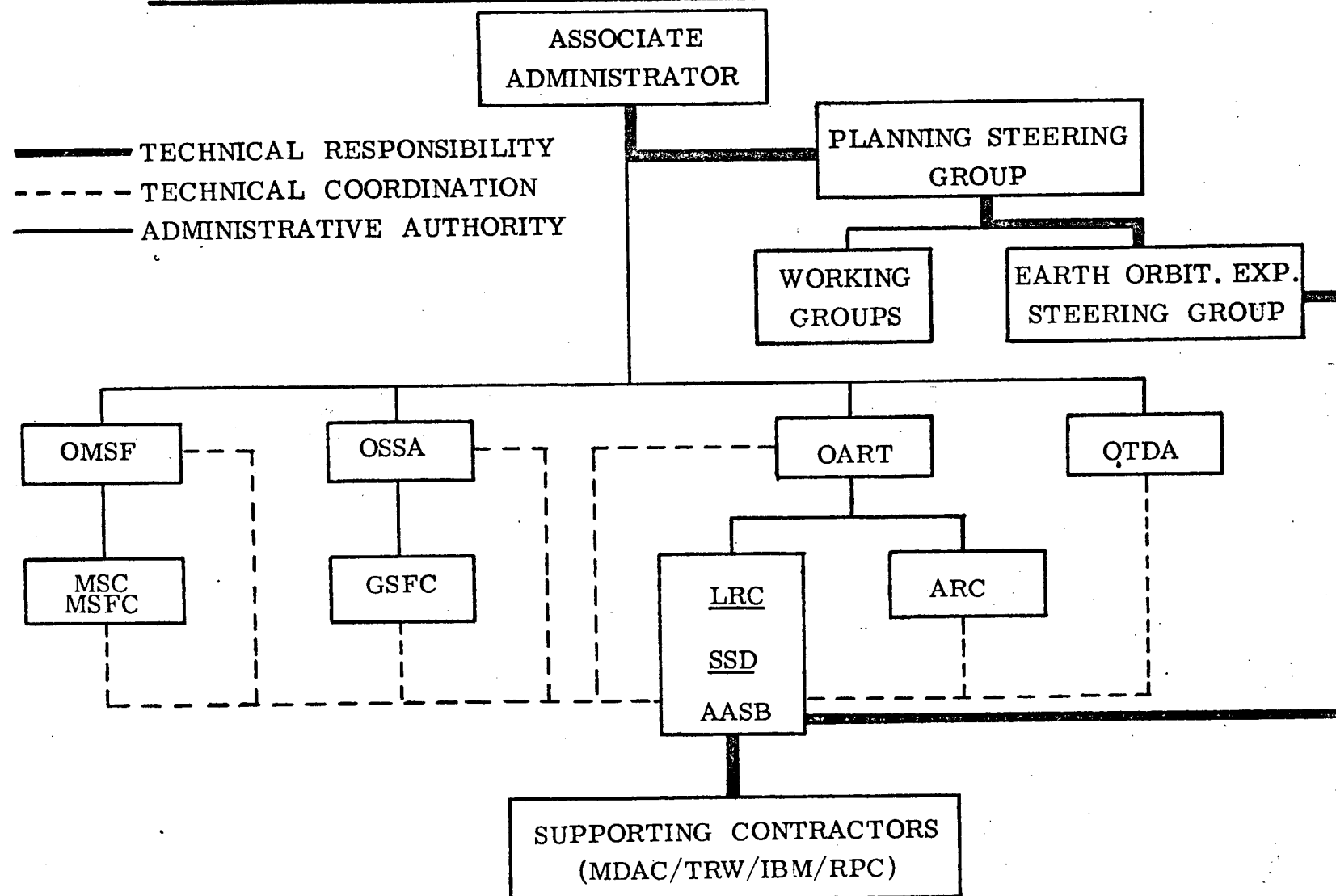


Figure 1. - Management Plan.

# EARTH ORBITAL EXPERIMENT PROGRAM AND REQUIREMENTS STUDY

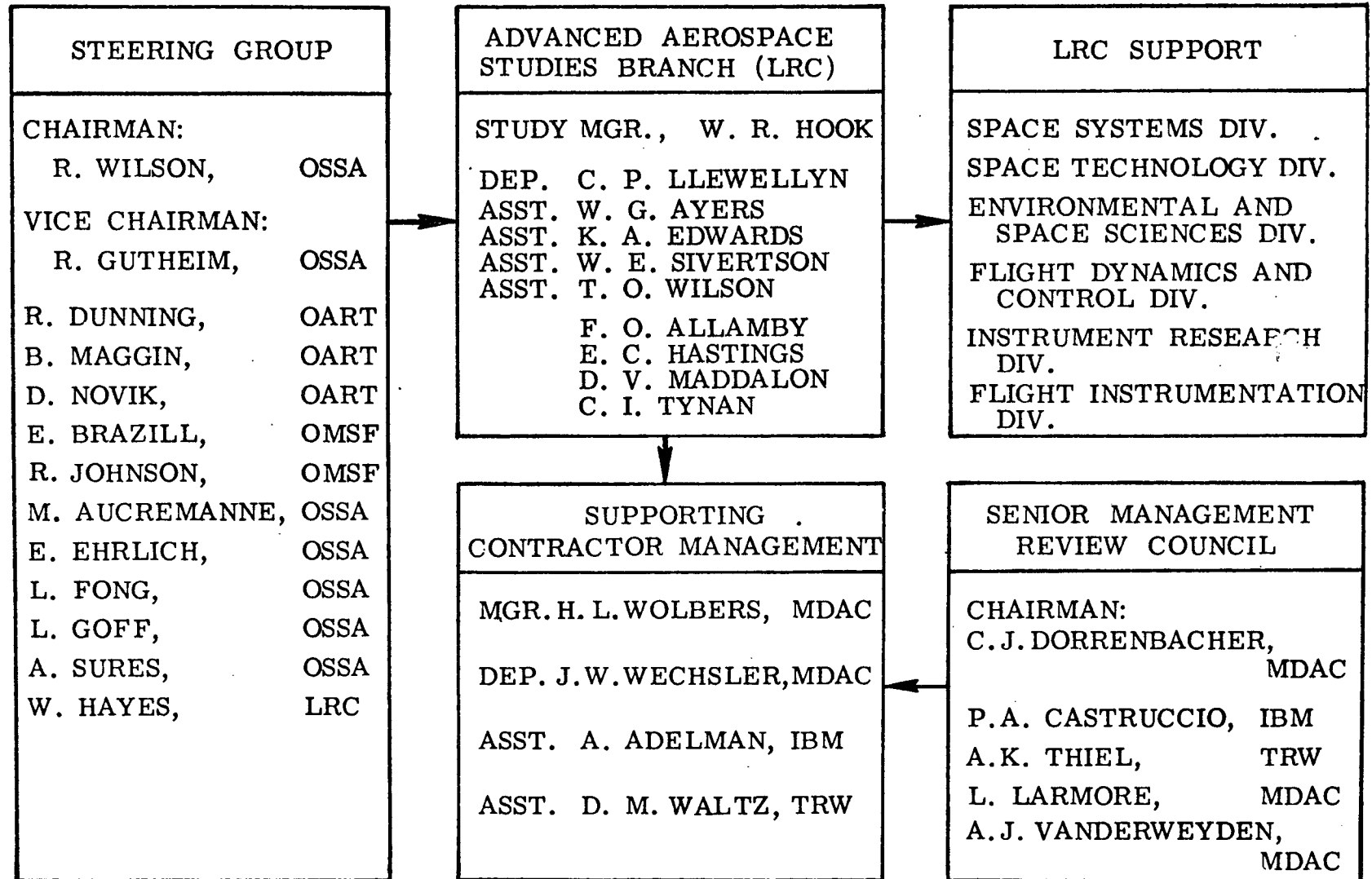


Figure 2. - Study Team.

**APPENDIX A**  
**ORGANIZED OVERVIEW CHARTS**

**SPACE BIOLOGY**

*A-i*

## APPENDIX A INTRODUCTION

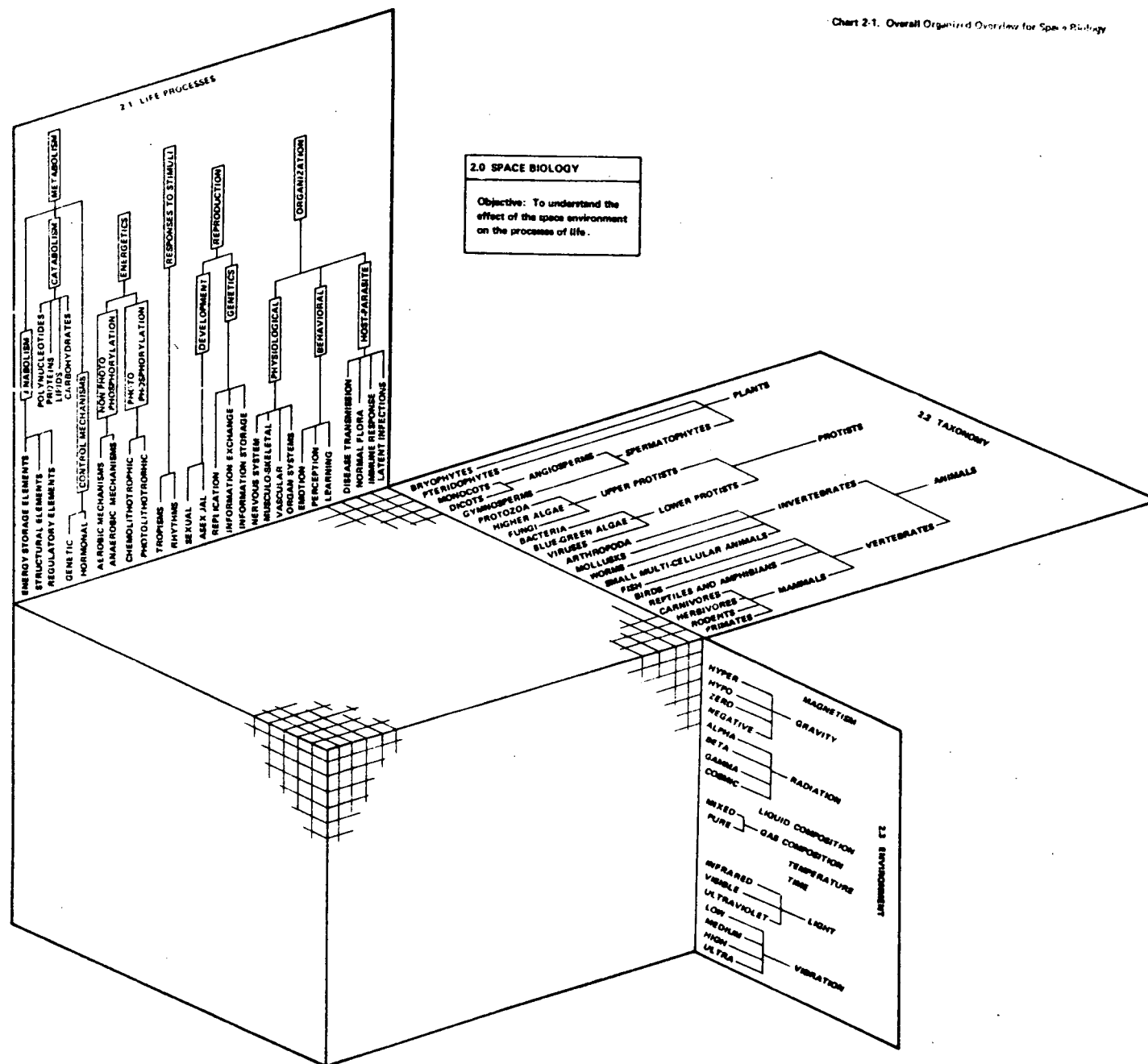
The organized overview method of analysis is described in Section 2, in general terms as well as specific detail for each of the six study disciplines. The organized overview charts derived in each of these disciplines are presented in this Appendix, as follows:

Manned Spaceflight Capability	Charts 1-1 through 1-90
Space Biology	Charts 2-1 through 2-14
Space Astronomy	Charts 3-1 through 3-42
Space Physics	Charts 4-1 through 4-17
Communications and Navigation	Charts 5-1 through 5-9
Earth Observations	Charts 6-1 through 6-29

Critical issues referred to at the lower levels of these charts are found in Tables 1 through 6 in Appendix B.



Chart 2-1. Overall Organized Overview for Space Biology



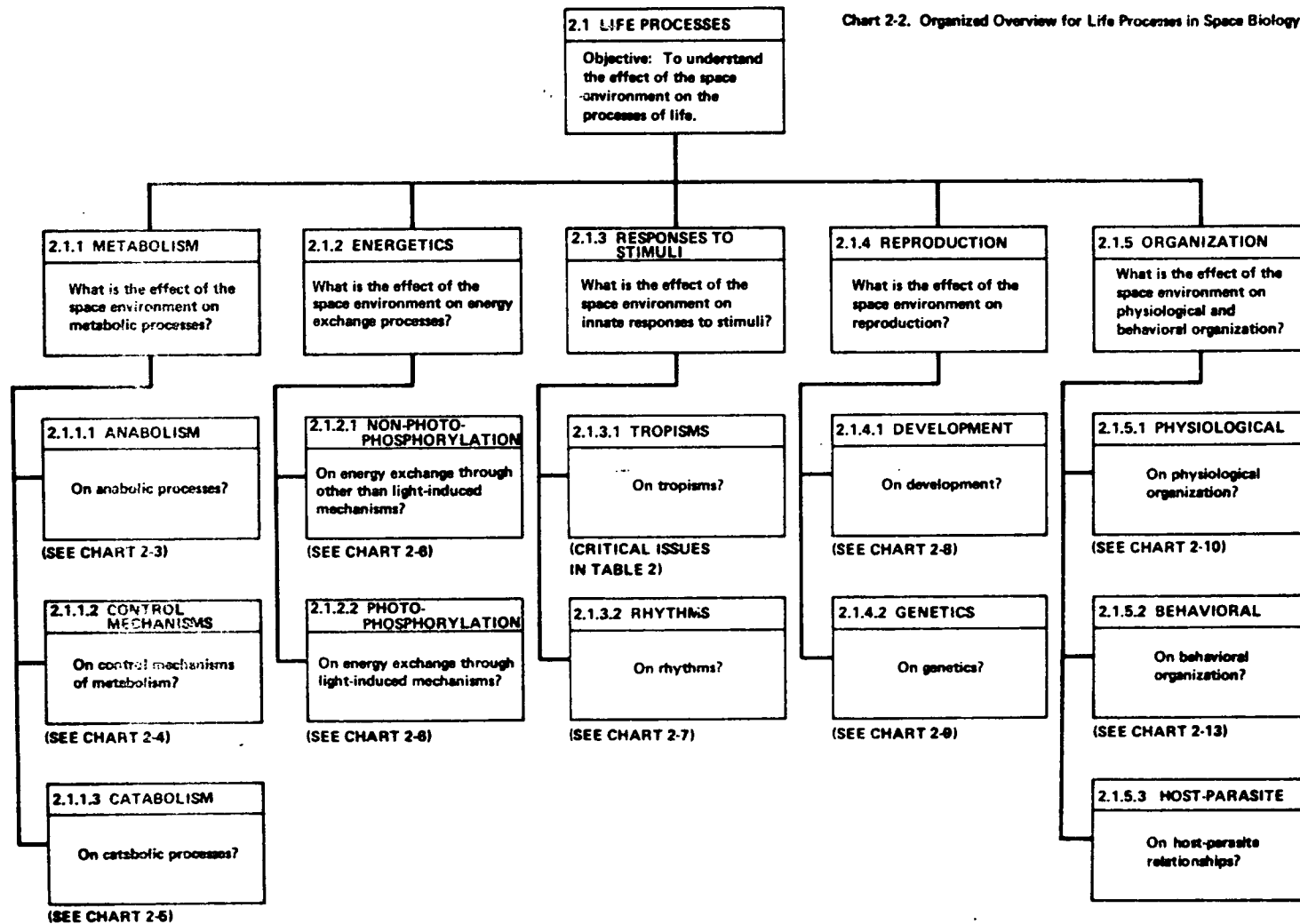


Chart 2-2. Organized Overview for Life Processes in Space Biology

Chart 2-3. Space Biology – Anabolic Processes of Metabolism

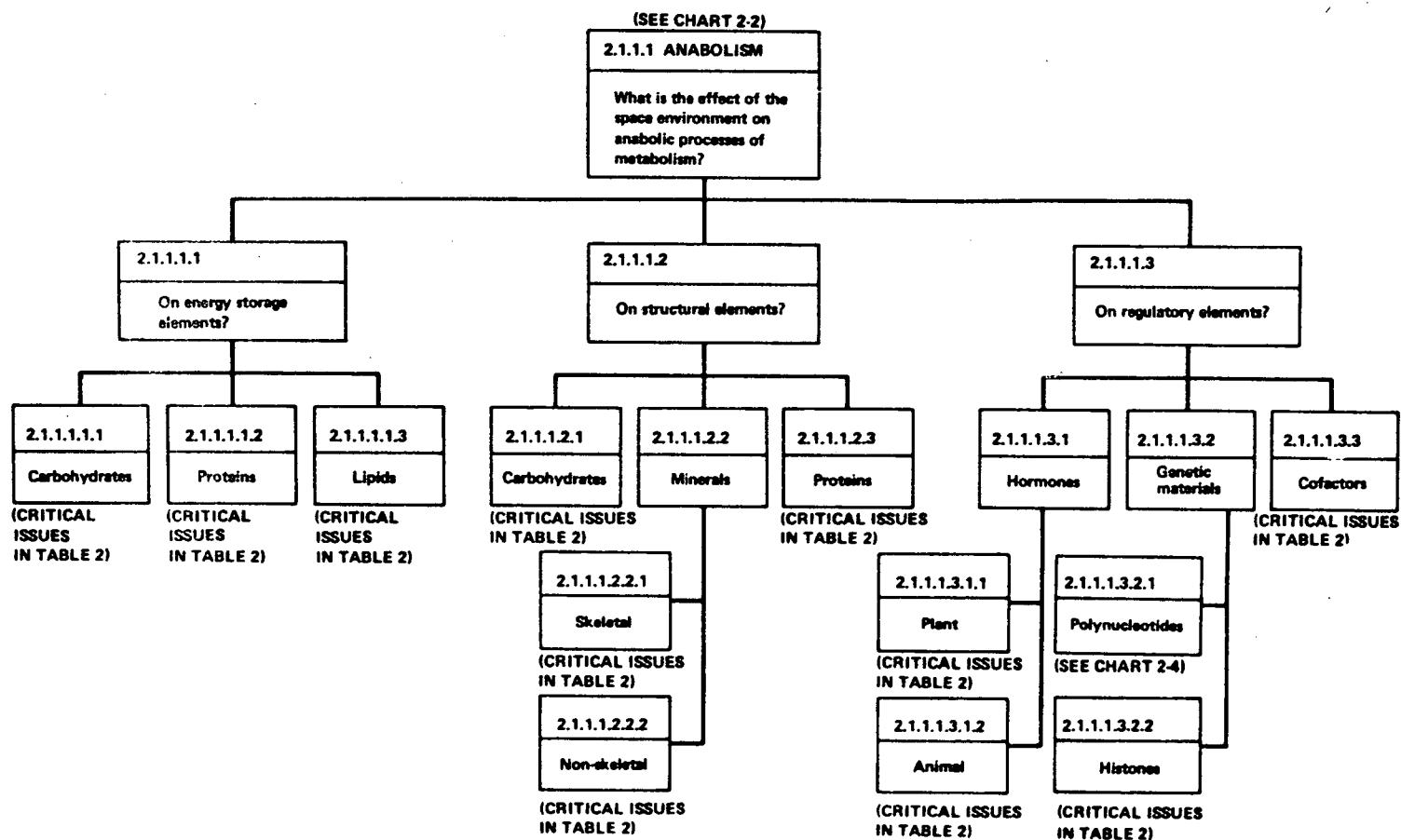


Chart 2-4. Space Biology – Polynucleotides in Anabolism and Metabolic Control Mechanisms

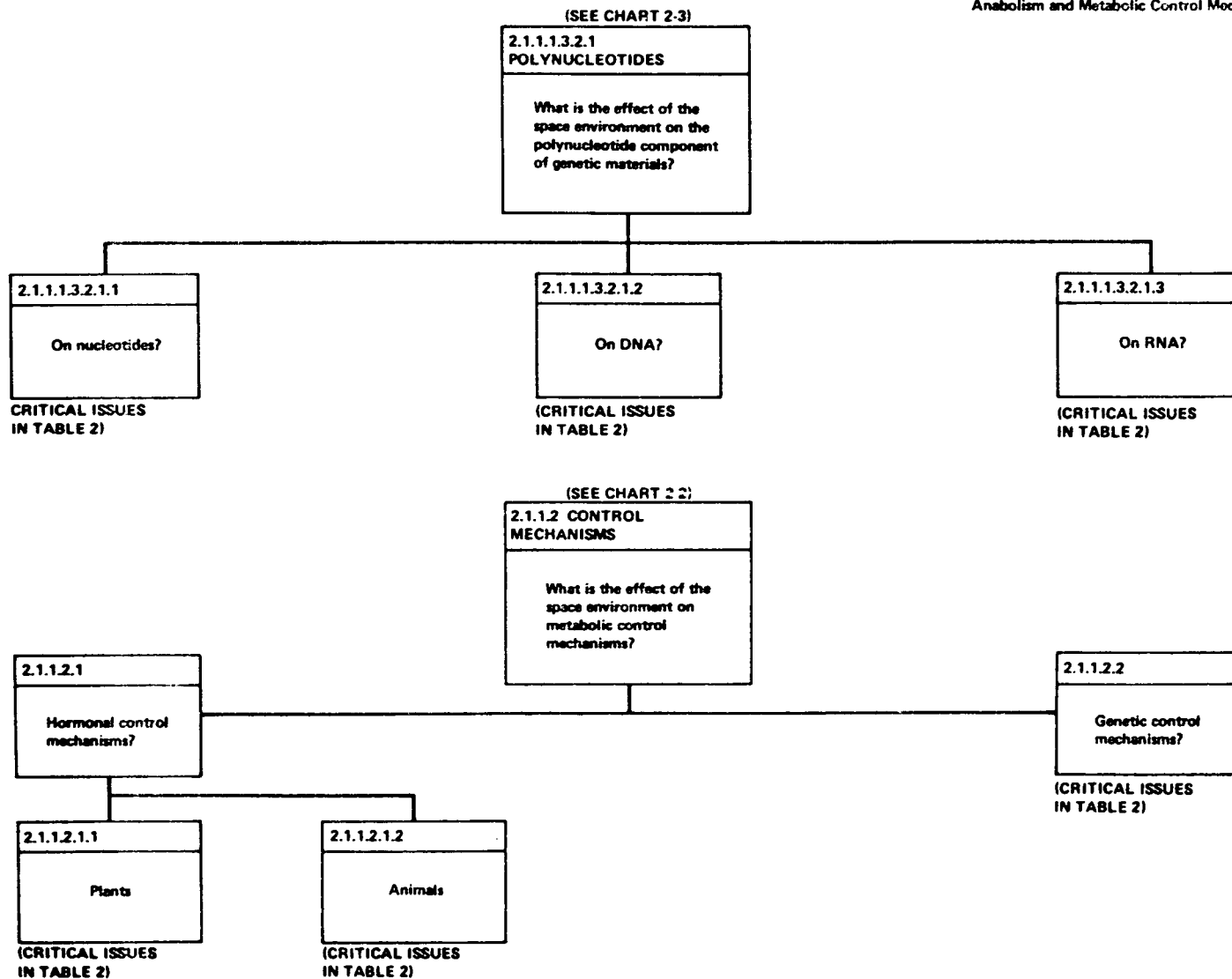
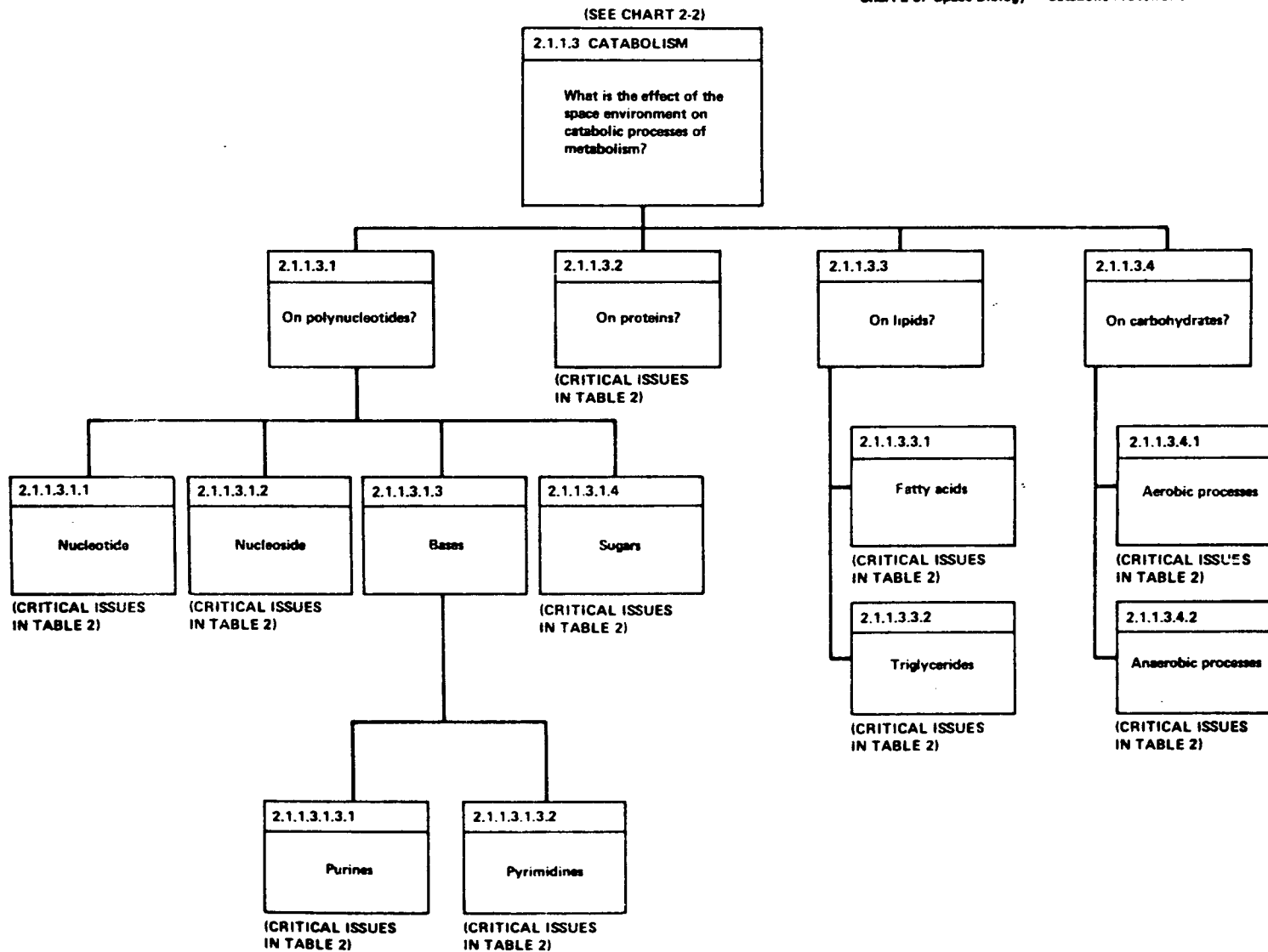
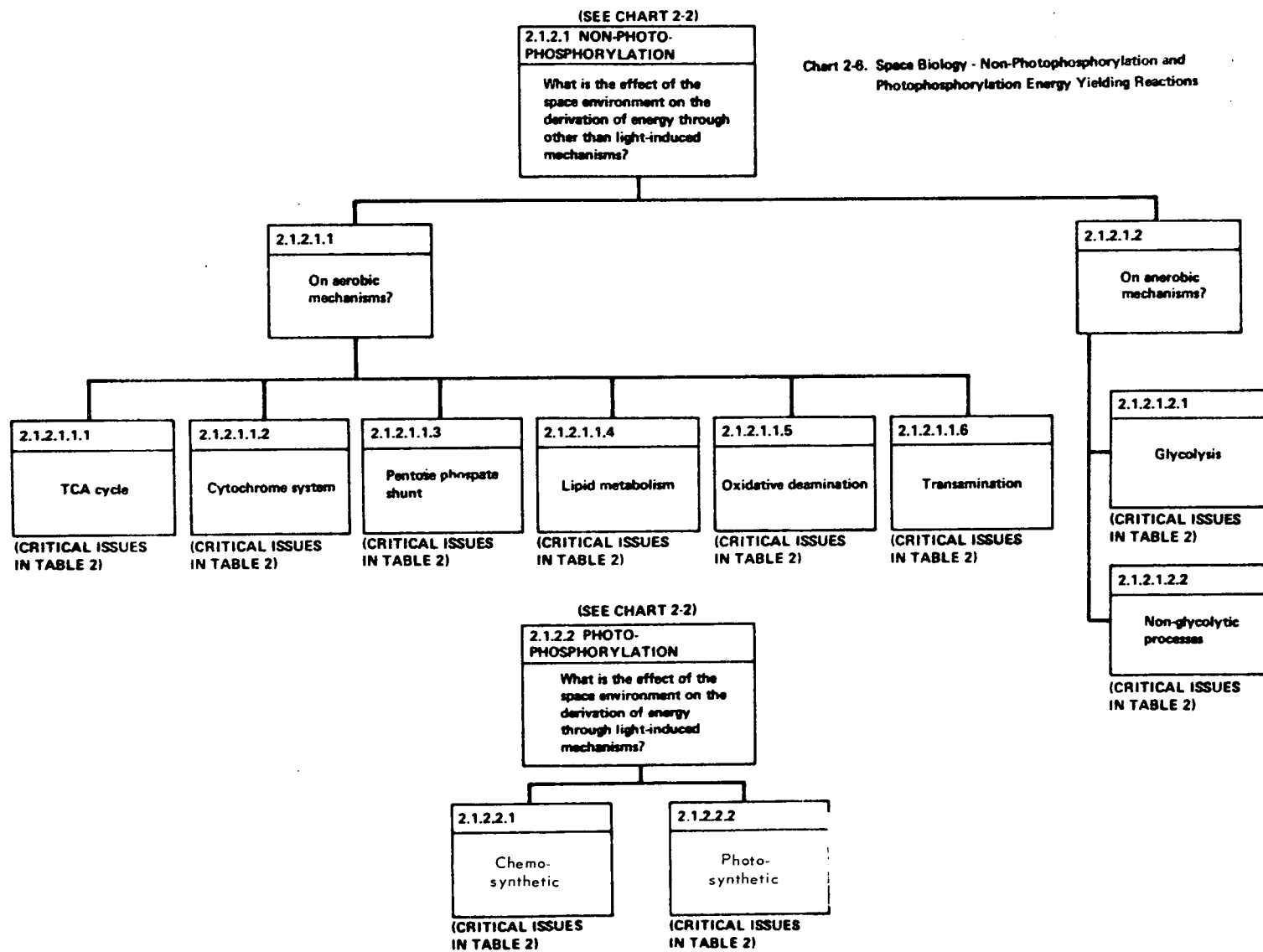


Chart 2-5. Space Biology – Catabolic Processes of Metabolism





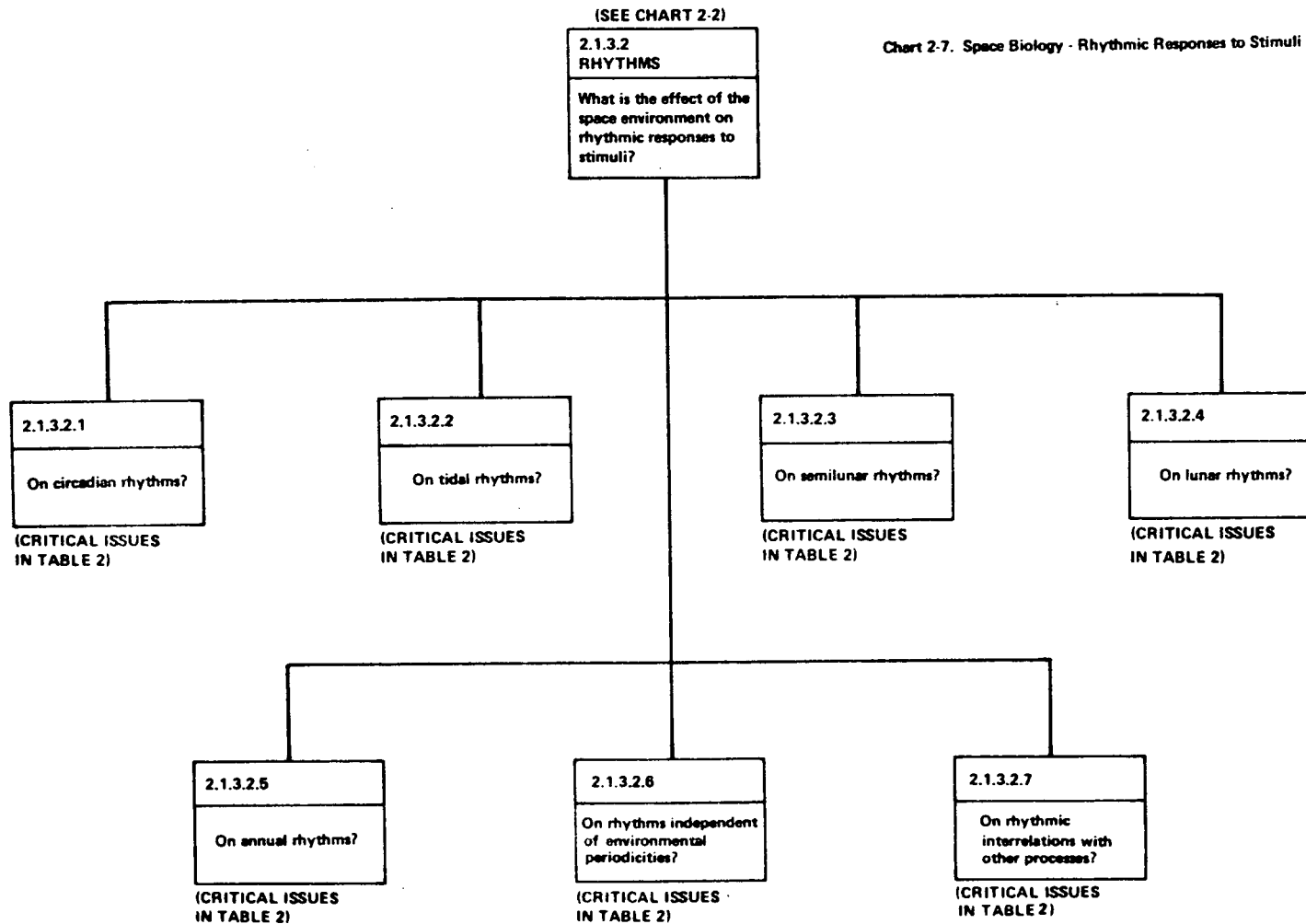
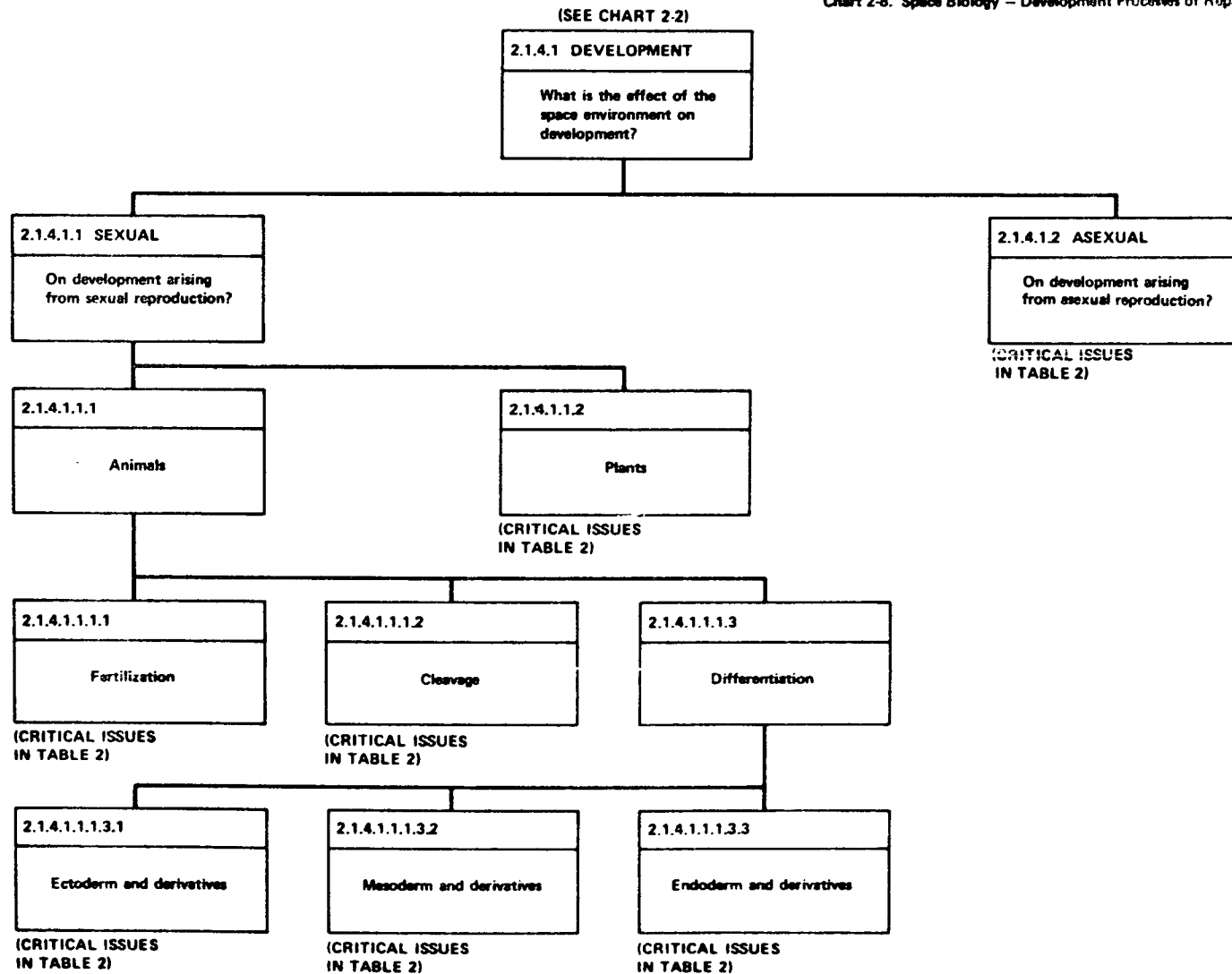


Chart 2-8. Space Biology -- Development Processes of Reproduction





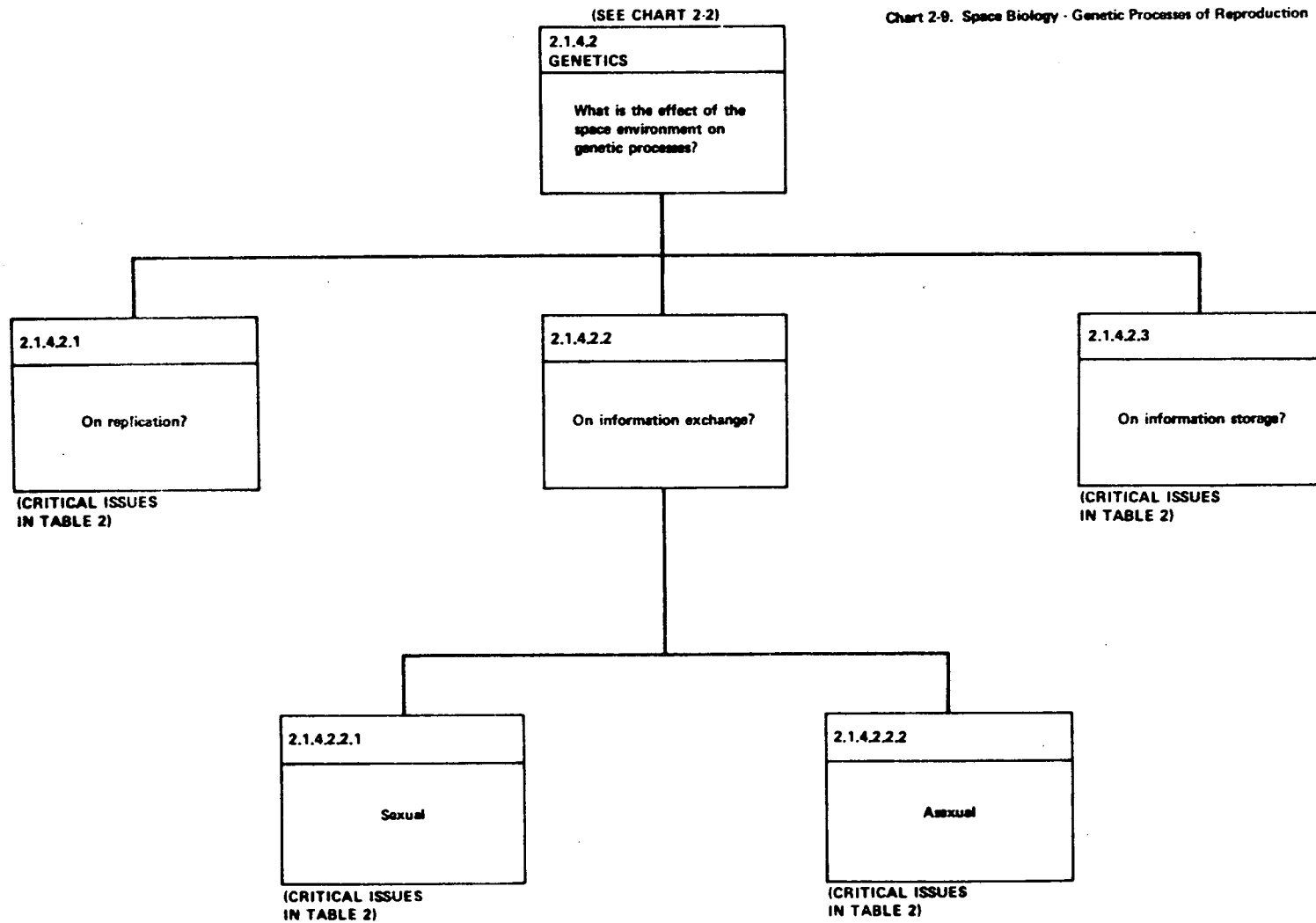
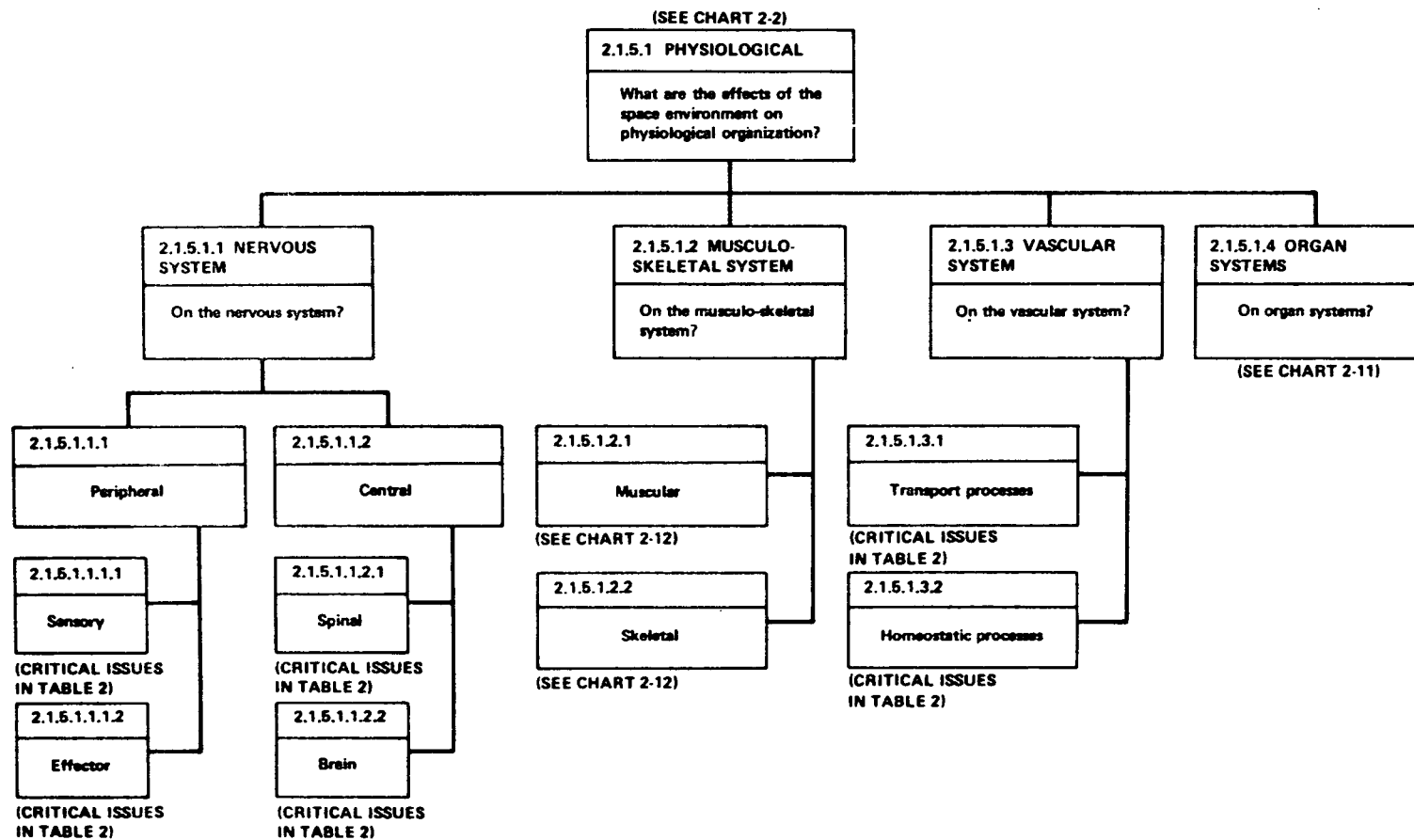


Chart 2-10. Space Biology – Physiological Organization



(SEE CHART 2 10)

Chart 2-11. Space Biology - Physiological Effects on Organ Systems

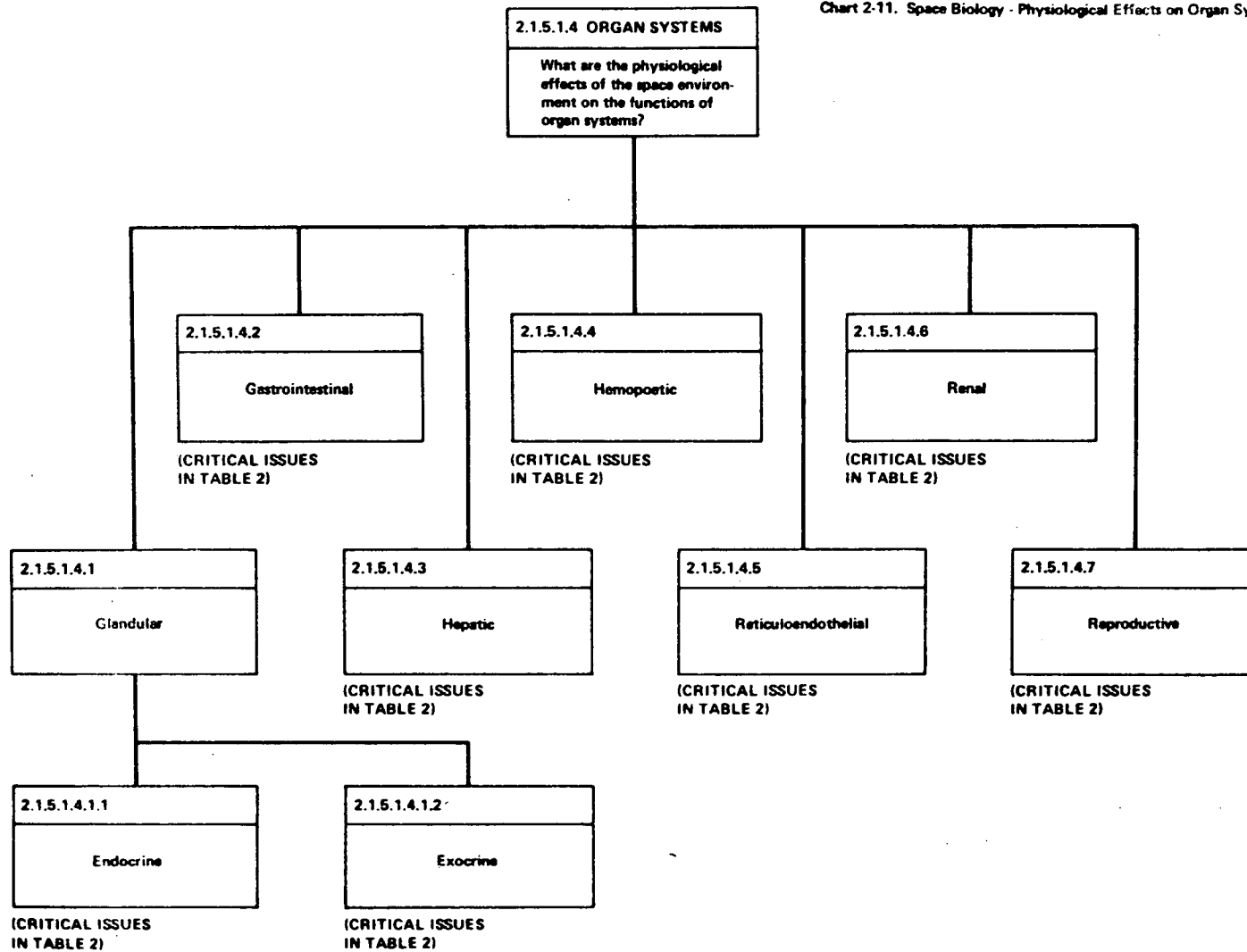
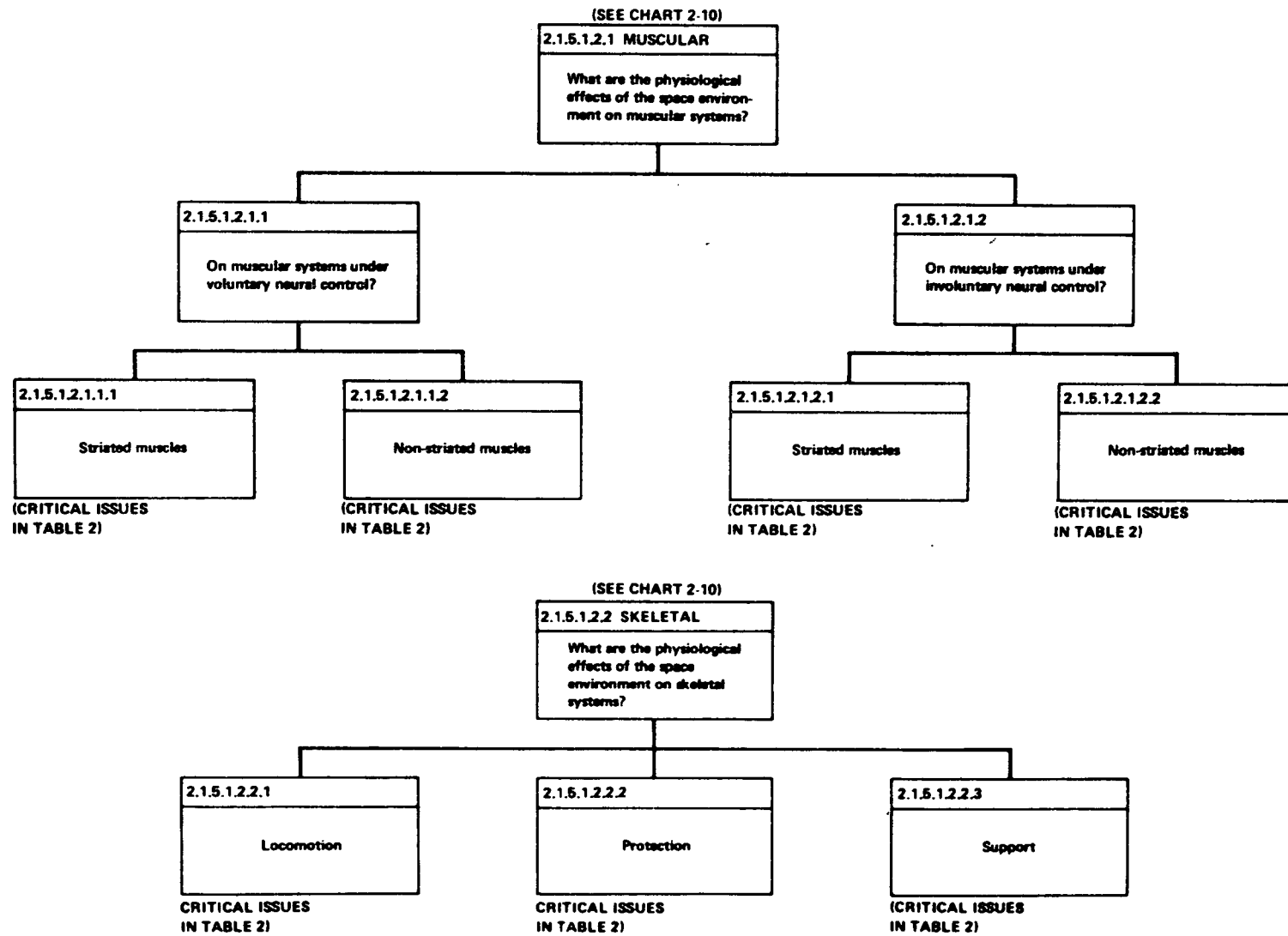
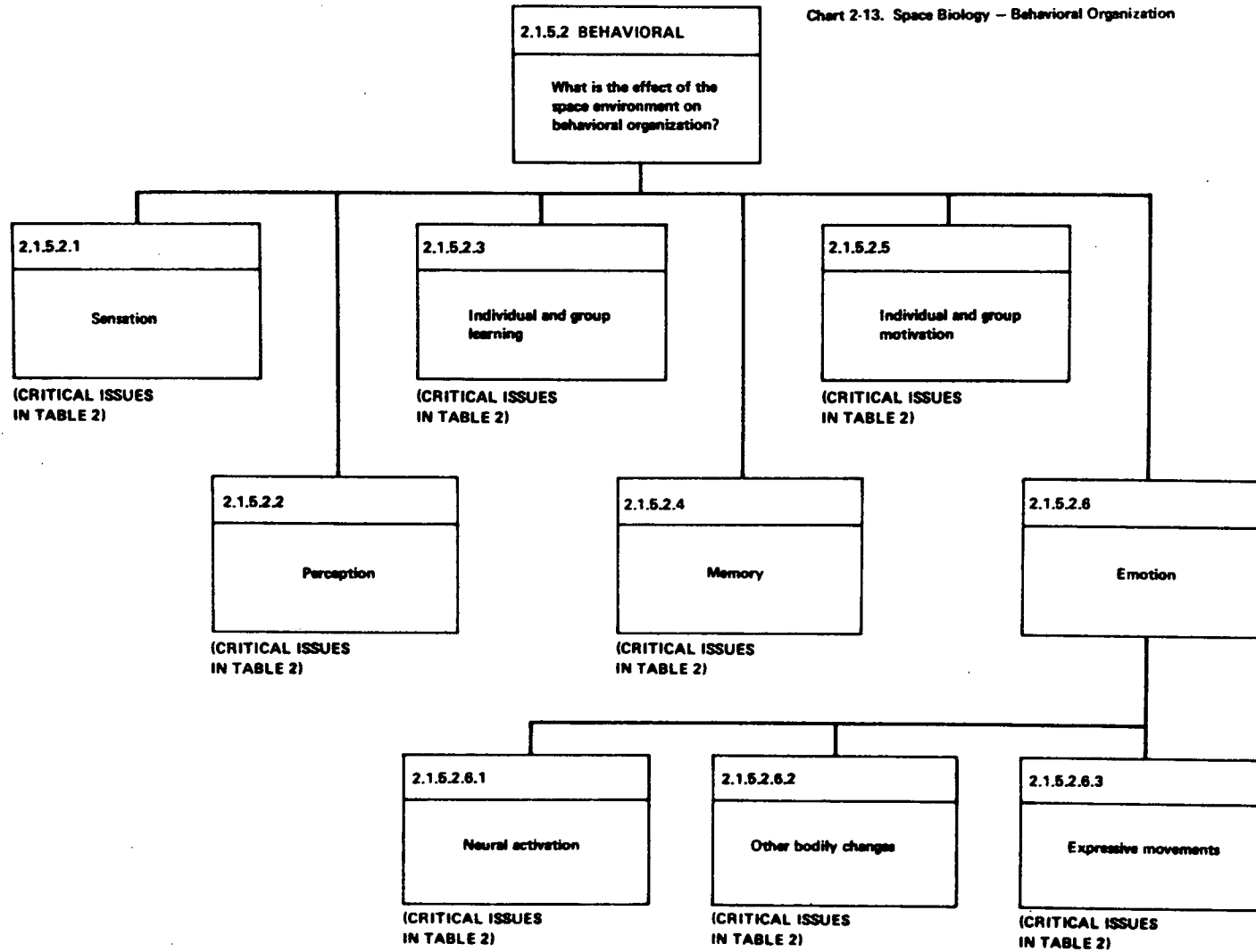


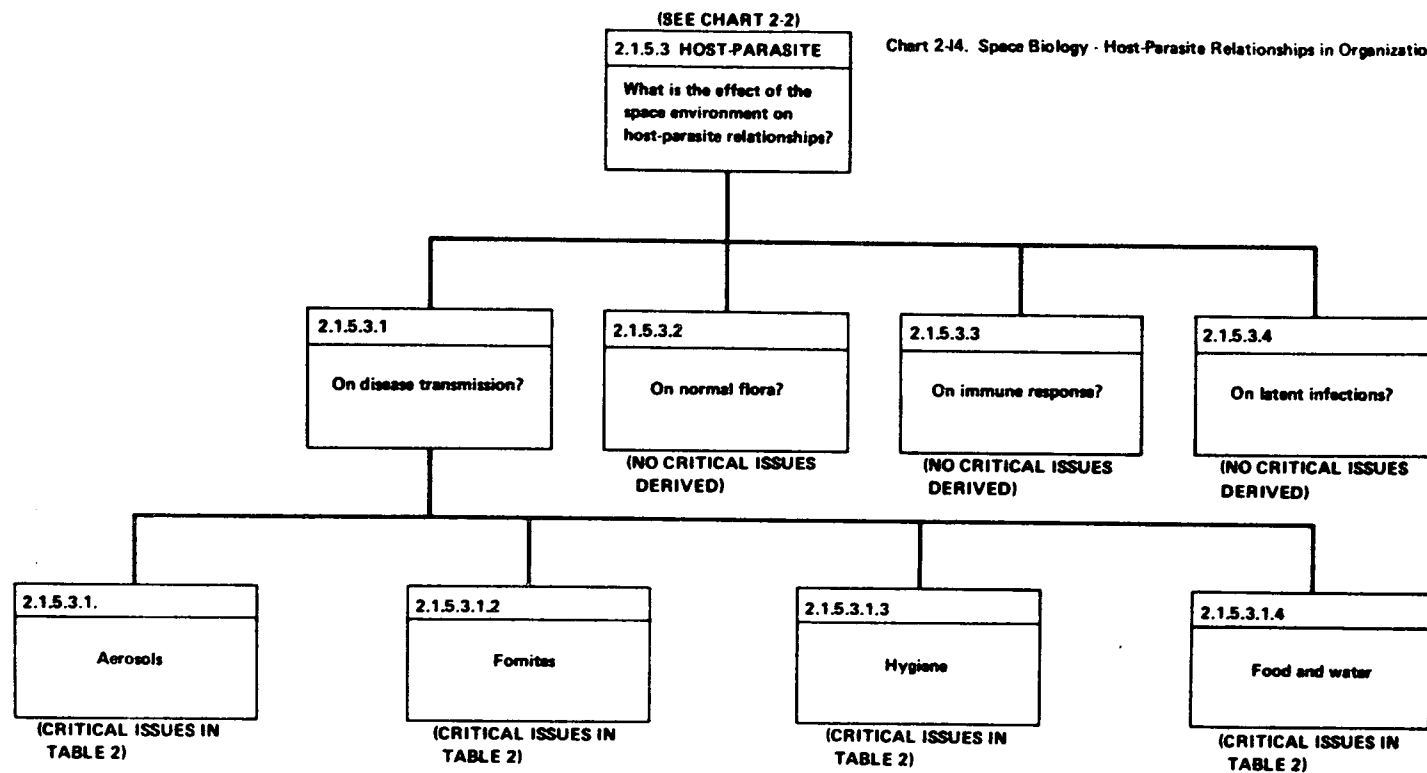
Chart 2-12. Space Biology – Physiological Effects on Muscular and Skeletal Systems



(SEE CHART 2-2)

Chart 2-13. Space Biology – Behavioral Organization





**APPENDIX B**  
**CRITICAL ISSUES**

**SPACE BIOLOGY**

*B-1*

## Appendix E INTRODUCTION

This appendix presents the series of 3,800 critical issues that comprise the principal result of the organized overview analysis of objectives for the six scientific and technical disciplines. The organized overview is described in Section 2 and graphically displayed in the charts contained in Appendix A.

In order to maintain the traceable indexing system carried through the charts shown in Appendix A, the numbers are repeated as major headings in Appendix B. Each critical issue thereby retains identity with the objectives and subobjectives from which it was derived.

The results of further analysis of the critical issues during the latter phases of the study are combined with the tabulation in this appendix by entering a code in the margin of the page, specifying the eventual disposition action. Table B-1 explains the code used for this assignment of critical issues.

In using Table B-1 to trace out the disposition, it is helpful to note that the principal consideration is whether or not the critical issue is addressed in at least one research cluster. In cases where this has occurred, the identifying serial number of the research cluster is used as the code. The alternative (2-letter) codes refer to categorical assignments of critical issues not included in the research cluster descriptions.

A summary of the disposition of the 3,800 critical issues in the six disciplines, according to the coding protocol of Table B-1, is presented in Table B-2.



Table B-1  
CODE FOR DISPOSITION OF CRITICAL ISSUES

---

**X-AB-YY    Addressed in Research Cluster No. X-AB-XY**

The first number (X) indicates the scientific or technical discipline, i. e.,

- 1 - Manned Spaceflight Capability
- 2 - Space Biology
- 3 - Space Astronomy
- 4 - Space Physics
- 5 - Communications and Navigation
- 6 - Earth Observations

The one- or two-letter code (AB) indicates the subdiscipline area, e. g.,

- BR    - Behavioral Research
- PP    - Plasma Physics Laboratory
- A/F   - Agriculture, Forest, and Range Resources

The final number (YY) is a sequence number within the subdiscipline. Thus, 4-PP-3 is the third research cluster in the Plasma Physics Laboratory subdiscipline of the Space Physics discipline.

**PS        Eliminated by Preliminary Screening**

Critical issue considered to be essentially peripheral to the scope of Earth orbital research. These issues were included in the report for the ideas that they might stimulate, but were not analyzed further.

**NS        Eliminated: Not an Earth Orbital Research Candidate**

Critical issue judged to be more appropriate to research based elsewhere—terrestrial, sub-orbital, interplanetary trajectories, extraterrestrial bodies, etc.—after considering the advantages and disadvantages of various orbits and of the space environment.

**UM        Eliminated: Not a Manned Earth Orbital Research Candidate**

Critical issue judged to be better suited to automated spacecraft than to manned Earth orbital research facilities, due either to the inability of man to contribute meaningfully to the research or to detrimental effects of man's presence.

Table B-1  
CODE FOR DISPOSITION OF CRITICAL ISSUES (Continued)

OP	<u>Eliminated: Covered in Ongoing Programs</u>  Critical issue whose research requirements are expected to be satisfied from the results of programs already in progress or firmly planned.
AC	<u>Deferred, Due to Requirements for Advanced Concepts</u>  Critical issue for which no experimental approach is currently available, or for which advanced study or advanced ground-based developments should precede further programmatic analysis.
MS, SB, SA, SP, CN, or EO	<u>Principally Concerned with Another Discipline</u>  Critical issue included in the organized overview analysis of a given discipline for the sake of completeness, but which is actually more germane to another discipline (indicated by symbol) and is analyzed further in that discipline.

Table B-2  
DISPOSITION OF CRITICAL ISSUES

Code \ Discipline	Manned Spaceflight Capability	Space Biology	Space Astronomy	Space Physics	Communica- tions and Navigation	Earth Observations	Totals
In Research Cluster Cluster (X-AB-YY)	785	361	154	154	90	439	1,983
Preliminary Screening (PS)	330	0	155	15	0	36	536
Not Earth Orbital (NS)	187	0	240	49	81	137	694
Not Manned Earth Orbital (UM)	0	0	21	23	0	35	79
Covered in Ongoing Programs (OP)	72	0	0	0	14	1	87
Requires Advanced Concepts (AC)	81	2	156	0	122	9	370
Referred to Another Discipline (MS, SB, etc.)	13	0	26	3	8	1	51
Totals	1,468	363	752	244	315	658	3,800

TABLE 2  
SPACE BIOLOGY CRITICAL ISSUES

2.1 LIFE PROCESSES

2.1.1 METABOLISM

2.1.1.1 Anabolism

2.1.1.1.1 Energy Storage Elements

2.1.1.1.1.1 Carbohydrates

What is the effect of the space environment on the biosynthesis of:

.1 Starch?	2-IN-2,3; 2-P/T-2; 2-PL-1,2,3
.2 Fructosans?	2-PL-1,2,3
.3 Mannans?	2-PL-1,2,3
.4 Glycogen?	2-VB-1,2,3; 2-IN-1,2,3
.5 Dextran?	2-PL-1,2,3; 2-P/T-1,2,3
.6 Inulin?	2-PL-1,2,3
.7 Other Polysaccharides?	2-IN-2,3; 2-VB-1,2,3

2.1.1.1.1.2 Protein Energy Storage Elements

What is the effect of the space environment on the biosynthesis of:

.1 Creatine phosphate?	2-IN-2,3; 2-VB-2,3
------------------------	--------------------

2.1.1.1.1.3 Lipid Energy Storage Elements

---

What is the effect of the space environment on the biosynthesis of:

. 1 Acetyl Coenzyme-A?

2-P/T-1,2,3; 2-IN-1,2,3 2-PL-1,2,3 2-VB-2,3

2.1.1.1.2 Anabolism of Structural Elements

2.1.1.1.2.1 Carbohydrates

What is the effect of the space environment on the biosynthesis of:

. 1 Chitin?

2-IN-1,2,3 2-VB-1,2,3

. 2 Cellulose?

2-PL-1,2,3 2-P/T-1,2,3

. 3 Xylan?

2-PL-1,2,3 2-P/T-1,2,3

. 4 Arabinose?

2-PL-1,2,3 2-P/T-1,2,3

. 5 Mannose?

2-PL-1,2,3 2-P/T-1,2,3

. 6 Lignin?

2-PL-1,2,3

. 7 Other polysaccharides?

2-IN-2,3; 2-PL-2,3

2.1.1.1.2.2 Mineral Structural Elements

2.1.1.1.2.2.1 Skeletal Minerals

What is the effect of the space environment on the anabolism of:

. 1 Calcium?

2-PL-1,2,3 2-IN-1,2,3 2-VB-1,2,3

. 2 Phosphorus?

2-IN-1,2,3 2-VB-1,2,3

. 3 Other skeletal minerals?

2-PL-1,2,3 2-IN-1,2,3 2-VB-1,2,3

2.1.1.1.2.2.2 Nonskeletal Minerals

What is the effect of the space environment on the anabolism of:

. 1 Sodium?

2-IN-2,3; 2-PL-2,3; 2-VB-2,3; 2-P/T-2,3

. 2 Potassium?

2-IN-2,3; 2-PL-2,3; 2-VB-2,3; 2-P/T-2,3

. 3 Chloride?

2-IN-2,3; 2-PL-2,3; 2-VB-2,3; 2-P/T-2,3

. 4 Other nonskeletal minerals?

2-IN-2,3; 2-PL-2,3; 2-VB-2,3; 2-P/T-2,3

### 2.1.1.1.2.3 Protein Structural Elements

What is the effect of the space environment on the biosynthesis of:

- |                     |                   |
|---------------------|-------------------|
| . 1 Muscle protein? | 2-IN-2,3 2-VB-2,3 |
| . 2 Collagen?       | 2-IN-2,3 2-VB-2,3 |
| . 3 Other proteins? | 2-IN-2,3 2-VB-2,3 |

### 2.1.1.1.3 Regulatory Elements of Anabolism

#### 2.1.1.1.3.1 Hormones

##### 2.1.1.1.3.1.1 Plant

What is the effect of the space environment on the biosynthesis of:

- |                   |          |
|-------------------|----------|
| . 1 Auxins?       | 2-PL-2,3 |
| . 2 Kinetins?     | 2-PL-2,3 |
| . 3 Gibberellins? | 2-PL-2,3 |

##### 2.1.1.1.3.1.2 Animal

What is the effect of the space environment on the biosynthesis of:

- |                                |               |
|--------------------------------|---------------|
| . 1 Thyroid hormones?          | 2-VB-2        |
| . 2 Parathyroid hormones?      | 2-VB-2        |
| . 3 Gonadal hormones?          | 2-IN-2 2-VB-2 |
| . 4 Adrenal cortical hormones? | 2-VB-2        |
| . 5 Adrenal medulla hormones?  | 2-VB-2        |
| . 6 Pancreatic hormones?       | 2-VB-2        |
| . 7 Other hormones?            | 2-IN-2 2-VB-2 |

#### 2.1.1.1.3.2 Genetic materials

##### 2.1.1.1.3.2.1 Polynucleotides

#### 2.1.1.1.3.2.1.1 Nucleotides

What is the effect of the space environment on the biosynthesis of:

- |     |                    |                                |
|-----|--------------------|--------------------------------|
| . 1 | ATP?               | 2-IN-3 2-PL-2,3 2-VB-2 2-P/T-2 |
| . 2 | UTP?               | 2-IN-3 2-PL-2,3 2-VB-2 2-P/T-2 |
| . 3 | GTP?               | 2-IN-3 2-PL-2,3 2-VB-2 2-P/T-2 |
| . 4 | Other nucleotides? | 2-IN-3 2-PL-2,3 2-VB-2 2-P/T-2 |

#### 2.1.1.1.3.2.1.2 What is the effect of the space environment on the biosynthesis of DNA?

2-VB-2,3 2-IN-2,3 2-PL-2,3 2-P/T-2,3

#### 2.1.1.1.3.2.1.3 RNA

What is the effect of the space environment on the biosynthesis of:

- |     |                |                                    |
|-----|----------------|------------------------------------|
| . 1 | Messenger RNA? | 2-VB-2,3 2-IN-3 2-PL-2,3 2-P/T-2,3 |
| . 2 | Transfer RNA?  | 2-VB-2,3 2-IN-3 2-PL-2,3 2-P/T-2,3 |
| . 3 | Ribosomal RNA? | 2-VB-2,3 2-IN-3 2-PL-2,3 2-P/T-2,3 |
| . 4 | Other RNAs?    | 2-VB-2,3 2-IN-3 2-PL-2,3 2-P/T-2,3 |

#### 2.1.1.1.3.2.2 What is the effect of the space environment on the biosynthesis of histones?

2-VB-2,3 2-IN-3 2-PL-3

#### 2.1.1.1.3.3 Enzyme Cofactors

What is the effect of the space environment on the biosynthesis of:

- |     |                         |                                    |
|-----|-------------------------|------------------------------------|
| . 1 | Coenzyme-A?             | 2-IN-3 2-P/T-2,3 2-PL-1,2,3 2-VB-2 |
| . 2 | Flavins?                | 2-IN-3 2-P/T-2,3 2-PL-1,2,3 2-VB-2 |
| . 3 | Biotin?                 | 2-IN-3 2-P/T-2,3 2-PL-1,2,3 2-VB-2 |
| . 4 | Nicotinic acid?         | 2-IN-3 2-P/T-2,3 2-PL-1,2,3 2-VB-2 |
| . 5 | Folic acid?             | 2-IN-3 2-P/T-2,3 2-PL-1,2,3 2-VB-2 |
| . 6 | Cobamide coenzyme?      | 2-IN-3 2-P/T-2,3 2-PL-1,2,3 2-VB-2 |
| . 7 | Thiamine cocarboxylase? | 2-IN-3 2-P/T-2,3 2-PL-1,2,3 2-VB-2 |
| . 8 | Other enzyme cofactors? | 2-IN-3 2-PTT-2,3 2-PL-1,2,3 2-VB-2 |

## 2.1.1.2 Control Mechanisms

### 2.1.1.2.1 Hormonal

#### 2.1.1.2.1.1 Plant

What is the effect of the space environment on the metabolic control functions of:

- |                    |            |
|--------------------|------------|
| . 1 Auxins ?       | 2-PL-1,2,3 |
| . 2 Kinetins ?     | 2-PL-1,2,3 |
| . 3 Gibberellins ? | 2-PL-1,2,3 |

#### 2.1.1.2.1.2 Animal

What is the effect of the space environment on the metabolic control functions of:

- |                                |                 |
|--------------------------------|-----------------|
| . 1 Thyroid hormones?          | 2-VB-2,3        |
| . 2 Parathyroid hormones?      | 2-VB-2,3        |
| . 3 Gonadal hormones?          | 2-IN-3 2-VB-2,3 |
| . 4 Adrenal cortical hormones? | 2-VB-2,3        |
| . 5 Adrenal medulla hormones?  | 2-VB-2,3        |
| . 6 Pancreatic hormones?       | 2-VB-2,3        |
| . 7 Adenohypophyseal hormones? | 2-VB-2,3        |
| . 8 Neurohypophyseal hormones? | 2-VB-2,3        |
| . 9 Other hormones?            | 2-VB-2,3        |
|                                | 2-IN-3 2-VB-2,3 |

#### 2.1.1.2.2 Genetic Control Mechanisms of Metabolism

What is the effect of the space environment on the genetic processes resulting in:

- |  |         |
|--|---------|
| . 1 Positive feedback?   | 2-F/T-3 |
| . 2 Negative feedback?   | 2-F/T-3 |
| . 3 Will inborn errors in metabolism occur due to the space environment? | 2-VB-3  |

### 2.1.1.3 Catabolism

#### 2.1.1.3.1 Polynucleotide Breakdown

##### 2.1.1.3.1.1 Nucleotide Breakdown

What is the effect of the space environment on the breakdown of:

. 1	ATP?	2-IN-3 2-P/T-2,3 2-PL-2,3 2-VB-2,3
. 2	UTP?	2-IN-3 2-P/T-2,3 2-PL-2,3 2-VB-2,3
. 3	ITP?	2-IN-3 2-P/T-2,3 2-PL-2,3 2-VB-2,3
. 4	GTP?	2-IN-3 2-P/T-2,3 2-PL-2,3 2-VB-2,3

##### 2.1.1.3.1.2 Nucleoside Breakdown

What is the effect of the space environment on the breakdown of:

. 1	Adenosine?	2-IN-3 2-P/T-2,3 2-PL-2,3 2-VB-2
. 2	Cytidine?	2-IN-3 2-P/T-2,3 2-PL-2,3 2-VB-2
. 3	Inosine?	2-IN-3 2-P/T-2,3 2-PL-2,3 2-VB-2
. 4	Guanosine?	2-IN-3 2-P/T-2,3 2-PL-2,3 2-VB-2

##### 2.1.1.3.1.3 Catabolism of Bases

###### 2.1.1.3.1.3.1 Purines

What is the effect of the space environment on the breakdown of:

. 1	Adenine?	2-IN-3 2-PL-2,3 2-P/T-2,3 2-VB-2,3
. 2	Hypoxanthine?	2-IN-3 2-PL-2,3 2-P/T-2,3 2-VB-2,3
. 3	Xanthine?	2-IN-3 2-PL-2,3 2-P/T-2,3 2-VB-2,3
. 4	Guanine?	2-IN-3 2-PL-2,3 2-P/T-2,3 2-VB-2,3



#### 2.1.1.3.1.3.2 Pyrimidines

What is the effect of the space environment on the breakdown of:

- |              |                                    |
|--------------|------------------------------------|
| .1 Uracil?   | 2-IN-3 2-P/T-2,3 2-PL-2,3 2-VB-2,3 |
| .2 Cytosine? | 2-IN-3 2-P/T-2,3 2-PL-2,3 2-VB-2,3 |
| .3 Thymine?  | 2-IN-3 2-P/T-2,3 2-PL-2,3 2-VB-2,3 |

#### 2.1.1.3.1.4 Catabolism of Sugars

What is the effect of the space environment on the breakdown of:

- |                 |                                    |
|-----------------|------------------------------------|
| .1 Ribose?      | 2-IN-3 2-P/T-2,3 2-PL-2,3 2-VB-2,3 |
| .2 Deoxyribose? | 2-IN-3 2-P/T-2,3 2-PL-2,3 2-VB-2,3 |

#### 2.1.1.3.2 Catabolism of Proteins

What is the effect of the space environment on:

- |                          |  |
|--------------------------|--|
| .1 Glycogenic processes? | 2-IN-2,3 2-P/T-2,3 2-VB-2,3 2-PL-1,2,3 |
| .2 Amino acid pools?     | 2-IN-2,3 2-P/T-2,3 2-VB-2,3 2-PL-1,2,3 |
| .3 Ketogenic processes?  | 2-IN-2,3 2-P/T-2,3 2-VB-2,3 2-PL-1,2,3 |

#### 2.1.1.3.3 Catabolism of Lipids

##### 2.1.1.3.3.1 Fatty Acids

What is the effect of the space environment on the:

- |                                    |  |
|------------------------------------|--|
| .1 Beta-oxidation of fatty acids?  | 2-IN-2,3 2-P/T-2,3 2-VB-2,3 2-PL-1,2,3 |
| .2 Omega-oxidation of fatty acids? | 2-IN-2,3 2-P/T-2,3 2-VB-2,3 2-PL-1,2,3 |

##### 2.1.1.3.3.2 What is the effect of the space environment on the catabolism of triglycerides?

2-IN-2,3 2-PL-2,3 2-VB-2,3 2-P/T-2,3

#### 2.1.1.3.4 Catabolism of Carbohydrates

#### 2.1.1.3.4.1 Aerobic Processes

What is the effect of the space environment on carbohydrate catabolism through the:

- .1 Pentose phosphate shunt? 2-IN-2,3 2-VB-2,3 2-P/T-2,3 2-PL-2,3
- .2 TCA cycle? 2-IN-2,3 2-VB-2,3 2-P/T-2,3 2-PL-2,3

#### 2.1.1.3.4.2 Anaerobic Processes

What is the effect of the space environment on carbohydrate catabolism through:

- .1 Glycolytic mechanisms? 2-IN-2,3 2-VB-2,3 2-P/T-2,3 2-PL-2,3
- .2 Nonglycolytic mechanisms? 2-IN-2,3 2-VB-2,3 2-P/T-2,3 2-PL-2,3

#### 2.1.2 ENERGETICS

##### 2.1.2.1 Nonphotophosphorylation

- 2.1.2.1.1 Aerobic Mechanisms\* 2-PL-1; 2-IN-1; 2-P/T-1; 2-VB-1

##### 2.1.2.1.1.1 Tricarboxylic Acid (TCA) Cycle

What is the effect of the space environment on the reaction mediated by: 2-PL-1,2,3

- .1 The enzyme, pyruvic oxidase? 2-VB-2,3 2-P/T-2,3 2-IN-2,3

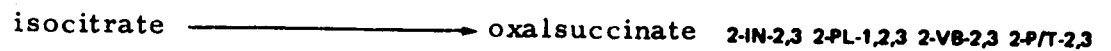
pyruvate —————→ acetyl CoA



---

\*This experiment calls for determining the effects of the environment on respiration of plants and animals in space by measuring oxygen and carbon dioxide.

- .2 The isocitric enzyme?



- .3 The enzyme, alpha ketoglutarate oxidase? 2-IN-2,3 2-PL-1,2,3 2-VB-2,3 2-P/T-2,3



- .4 The enzyme, succinyl thiokinase?



- .5 The enzyme, succinic dehydrogenase?



- .6 The enzyme, malic dehydrogenase?

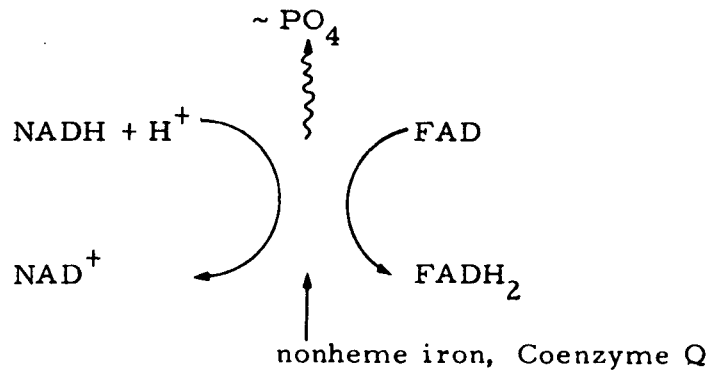


## 2.1.2.1.1.2 Cytochrome System

What is the effect of the space environment on the formation of ATP at:

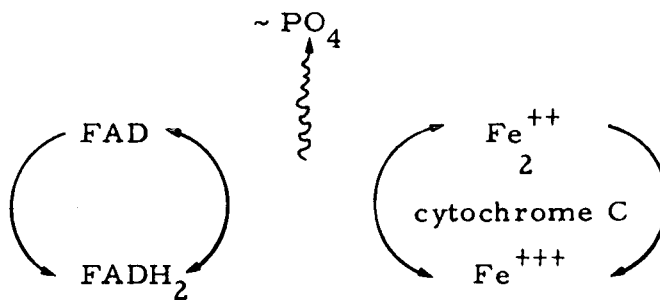
### .1 The NAD/FAD crossover point?

2-PL-2,3 2-VB-2,3 2-P/T-2,3 2-IN-3



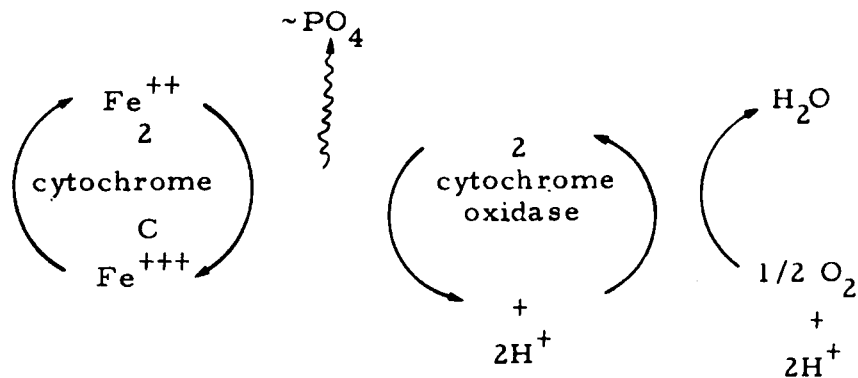
### .2 The FAD/cytochrome C crossover point?

2-PL-2,3 2-VB-2,3 2-P/T-2,3 2-IN-3



### .3 The Cytochrome C/cytochrome oxidase crossover point?

2-PL-2,3 2-VB-2,3 2-P/T-2,3 2-IN-3

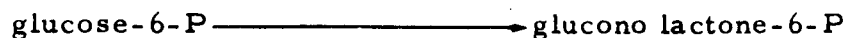


### 2.1.2.1.1.3 Pentose Phosphate Shunt for Carbohydrate Metabolism

What is the effect of the space environment on the reaction mediated by:

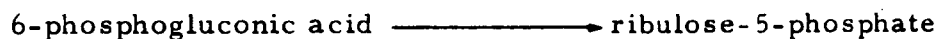
2-PL-1,2,3 2-P/T-2,3 2-VB-2,3 2-IN-2,3

- .1 The enzyme, glucose-6-phosphate dehydrogenase?



- .2 The enzyme, 6-phospho gluconic acid dehydrogenase?

2-PL-1,2,3 2-P/T-2,3 2-VB-2,3 2-IN-2,3

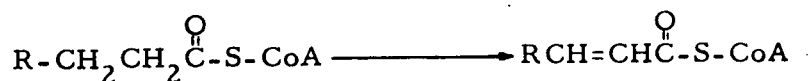


### 2.1.2.1.1.4 Lipid Metabolism (Beta-Oxidation)

What is the effect of the space environment on the reaction mediated by:

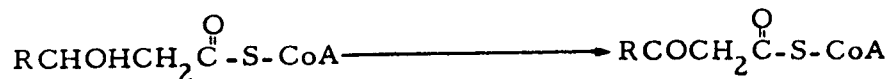
- .1 The enzyme, acyl dehydrogenase?

2-PL-1,2,3 2-P/T-2,3 2-VB-2,3 2-IN-2,3



- .2 The enzyme, hydroxyacyl dehydrogenase?

2-PL-1,2,3 2-P/T-2,3 2-VB-2,3 2-IN-2,3

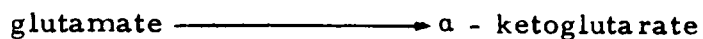


### 2.1.2.1.1.5 Oxidative Deamination

What is the effect of the space environment on the reaction mediated by:

- .1 Glutamic acid dehydrogenase

2-PL-1,2,3 2-VB-2,3 2-P/T-2,3 2-IN-2,3



- .2 D-Amino acid oxidase

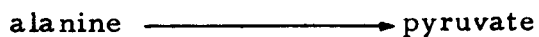
2-P/T-2,3



### 2.1.2.1.1.6 Transamination

- .1 What is the effect of the space environment on the reactions mediated by the transaminases?

2-PL-1,2,3 2-VB-2,3 2-P/T-2,3 2-IN-2,3



### 2.1.2.1.2 Anaerobic Mechanisms

## 2.1.2.1.2.1 Glycolysis

What is the effect of the space environment on the glycolytic reaction mediated by:

- .1 The enzyme, phosphoglyceraldehyde dehydrogenase? 2-PL-1,2,3 1-VB-2,3 2-P/T-2,3 2-IN-2,3  
 Glyceraldehyde - 3-P  $\rightleftharpoons$  1, 3 - diphosphoglyceric acid



- .2 The enzyme, phosphoglyceryl kinase? 2-PL-1,2,3 1-VB-2,3 2-P/T-2,3 2-IN-2,3  
 1, 3 diphosphoglyceric acid  $\longrightarrow$  3 phosphoglyceric acid



- .3 The enzyme, pyruvic oxidase? 2-PL-1,2,3 1-VB-2,3 2-P/T-2,3 2-IN-2,3  
 phosphoenolpyruvate  $\longrightarrow$  pyruvate



## 2.1.2.1.2.2 Nonglycolitic Mechanisms

What is the effect of the space environment on:

- .1 The enzyme, nitrate reductase? 2-P/T-2,3



- .2 The enzyme, sulfate reductase?



2P/T-2,3

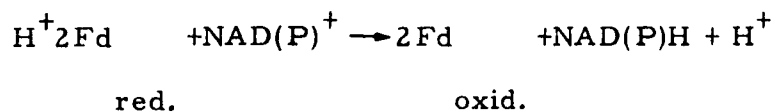


## 2.1.2.2 Photophosphorylation

### 2.1.2.2.1 Chemolithotropic Reactions

What is the effect of the space environment on the reaction mediated by:

- .1 The enzyme, transhydrogenase (ferridoxin/NAD(P) reductase)?



2P/T-2,3 2P/L-1,2,3

- .2 Chlorophyll?



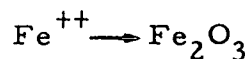
2P/T-3

### 2.1.2.2.2 Photolithotropic Reactions

What is the effect of the space environment on:

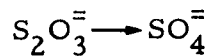
- .1 The oxidation of  $Fe^{++}$  to  $Fe_2O_3$ ?

2P/T-3



- .2 The oxidation of thiosulfate to sulfate?

2P/T-3





## 2.1.3 RESPONSES TO STIMULI

### 2.1.3.1 Tropisms

What is the effect of the space environment on:

- |     |  |                       |
|-----|--|-----------------------|
| . 1 | Geotropic response?  | 2-P/T-1 2-VB-1 2-PL-1 |
| . 2 | Phototropic response?  | 2-P/T-1 2-PL-1        |
| . 3 | Thermotropic response?   | 2-P/T-1 2-PL-1        |
| . 4 | Hydrotropic response?  | 2-P/T-1 2-PL-1        |
| . 5 | Chemotropic response?  | 2-P/T-1 2-PL-1        |
| . 6 | Possibility of an interaction between two or more of the tropic responses?                   | 2-PL-1,2,3 2-P/T-1    |
| . 7 | Any existing correlations between the tropic responses and metabolic or energetic reactions? | 2-PL-1,2,3 2-P/T-2,3  |

### 2.1.3.2 Rhythms

#### 2.1.3.2.1 Circadian Rhythms

What is the effect of the space environment on circadian rhythms, as manifested by:

- |     |   |                           |
|-----|---|---------------------------|
| . 1 | Organism activity?  | 2-IN-1 2-VB-1,2,3         |
| . 2 | Feeding?  | 2-IN-1 2-VB-1,2,3         |
| . 3 | Flower and leaf movements?  | 2-PL-1,2,3                |
| . 4 | Organic acid metabolism in succulents?                            | 2-PL-1,2,3                |
| . 5 | Phototaxis?   | 2-PL-1,2,3                |
| . 6 | Rate of photosynthesis?   | 2-P/T-1 2-PL-1,2,3        |
| . 7 | Bioluminescent flashes, glow rhythm, and photosynthetic capacity? | 2-P/T-1 2-PL-1,2,3        |
| . 8 | Cell division?  | 2-IN-1 2-P/T-1 2-PL-1,2,3 |
| . 9 | Root exudation?   | 2-PL-1,2,3                |

- .10 Fungal growth and spore discharge?
- .11 Odor production?
- .12 Excretion of urinary constituents?

2-P/T-1

2-P/T-1

2-VB-2

#### 2.1.3.2.2 Tidal Rhythms

What is the effect of the space environment on tidal rhythms, as manifested by:

- .1 Pumping rate of mussels?
- .2 Amphipod (Synchelidiam) emergence from sand?
- .3 Flatworm (Convoluta) emergence from sand?
- .4 Fucus respiratory rate?
- .5 Crab respiratory oxygen intake?
- .6 Amphipod (Talitrus) navigation?
- .7 Crab activity?
- .8 Crab color changes?
- .9 Diatom migration to mud surface?

2-IN-1

2-IN-1

2-IN-1

2-P/T-1

2-IN-1

2-IN-1

2-IN-1

2-IN-1

2-IN-1

#### 2.1.3.2.3 Semilunar Rhythms

What is the effect of the space environment on semilunar rhythms, as exhibited by:

- .1 Marine algae spore and gamete liberation?

2-PL-1

#### 2.1.3.2.4 Lunar Rhythms

What is the effect of the space environment on lunar rhythms, as exhibited by:

- .1 Palolo worm spawning?

2-IN-1

#### 2.1.3.2.5 Annual Rhythms

What is the effect of the space environment on annual rhythms:

- |     |   |            |
|-----|---|------------|
| . 1 | Resulting from photoperiodism?<br>or manifested by: | 2-PL-1     |
| . 2 | Hybernation (Depressed metabolism/Hypothermia)?     | 2-VB-1,2,3 |
| . 3 | Reproduction?                                       | 2-PT-1     |
| . 4 | Seed germination?                                   | 2-PL-1     |
| . 5 | Nitrate reduction capacity?                         | 2-PT-2     |
| . 6 | Growth rate of plants?                              | 2-PL-1     |

#### 2.1.3.2.6 Rhythms Independent of Environmental Periodicities

What is the effect of the space environment on rhythms which are independent of environmental periodicities, as exemplified by:

- |     |   |                  |
|-----|---|------------------|
| . 1 | Beating of flagella and cilia?              | 2-PT-1           |
| . 2 | Leaf movements?                             | 2-PL-1           |
| . 3 | Protoplasmic movement in the slime mold?    | 2-PL-1           |
| . 4 | Stomatal openings?                          | 2-PL-1           |
| . 5 | Variation in root tip electrical potential? | 2-PL-1           |
| . 6 | Shoot, root, and tendril growth?            | 2-PL-1           |
| . 7 | Flowering of bamboo?                        | 2-PL-1           |
| . 8 | Glycolytic enzyme oscillations?             | 2-IN-2, 2-PL-1,2 |

#### 2.1.3.2.7 Interrelations With Other Processes

What is the effect of the space environment on:

- |     |  |    |
|-----|--|----|
| . 1 | The interdependence of different rhythms within one type<br>and relative to other types? | AC |
| . 2 | The influence of metabolic and/or energetic reactions on<br>rhythmic processes?          | AC |

If metabolic and/or energetic reactions do influence rhythms in the space environment, is this a result of?

- . 1 Nuclear control? 2-IN-2,3 2-VB-2,3 2-PL-2,3
- . 2 Oscillations in membrane properties? 2-IN-3 2-VB-2,3 2-PL-2,3
- . 3 Interactions among subcellular organelles? 2-IN-2,3
- . 4 The indicator process? 2-IN-3 2-PL-2,3
- . 5 The basic (time-reference) oscillator? 2-IN-3 2-PL-2,3

## 2.1.4 REPRODUCTION

### 2.1.4.1 Development

#### 2.1.4.1.1 Sexual

##### 2.1.4.1.1.1 Animals

##### 2.1.4.1.1.1.1 Fertilization

What is the effect of the space environment on fertilization? 2-IN-1 2-VB-1,2,3

##### 2.1.4.1.1.1.2 Cleavage

What is the effect of the space environment on cleavage? 2-IN-1 2-VB-1,2,3

##### 2.1.4.1.1.1.3 Differentiation

What is the effect of the space environment on differentiation? 2-IN-2 2-VB-2,3

##### 2.1.4.1.1.1.3.1 Ectoderm and Derivatives

What is the effect of the space environment on the development of the:

- . 1 Ectoderm? 2-IN-1 2-VB-1
- . 2 Presumptive epidermis? 2-IN-1 2-VB-1
- . 3 Neural plate? 2-IN-1 2-VB-1
- . 4 Advanced ectodermal derivatives? 2-IN-1 2-VB-1

#### 2.1.4.1.1.1.3.2 Mesoderm and Derivatives

What is the effect of the space environment on the development of the:

- |                                      |               |
|--------------------------------------|---------------|
| . 1 Mesoderm?                        | 2-IN-1 2-VB-1 |
| . 2 Chorda?                          | 2-IN-1 2-VB-1 |
| . 3 Somites?                         | 2-IN-1 2-VB-1 |
| . 4 Nephrotome?                      | 2-IN-1 2-VB-1 |
| . 5 Lateral Plate?                   | 2-IN-1 2-VB-1 |
| . 6 Advanced mesodermal derivatives? | 2-IN-1 2-VB-1 |

#### 2.1.4.1.1.1.3.3 Endoderm and Derivatives

What is the effect of the space environment on the development of the:

- |                                      |               |
|--------------------------------------|---------------|
| . 1 Endoderm?                        | 2-IN-1 2-VB-1 |
| . 2 Advanced endodermal derivatives? | 2-IN-1 2-VB-1 |

#### 2.1.4.1.1.1.3.4 Transformation

2-IN-1 2-VB-1

#### 2.1.4.1.1.2 Plants

What is the effect of the space environment on plant sexual reproduction by:

- |   |            |
|---|------------|
| . 1 Isogametes?   | 2-PL-1,2,3 |
| . 2 Heterogametes?  | 2-PL-1     |
| If heterogametic reproduction is affected by the space environment, are the effects present in the: |            |
| . 1 Antheridium?  | 2-PL-1,2,3 |
| . 2 Oogonium?   | 2-PL-1,2,3 |

#### 2.1.4.1.2 Asexual

What is the effect of the space environment on:

- |  |        |
|--|--------|
| . 1 Motile sporophytes (zoospores)?          | 2-PT-1 |
| . 2 Nonmotile sporophytes (sporangiophores)? | 2-PT-1 |

## 2.1.4.2 Genetics

### 2.1.4.2.1 Replication

What effect does the space environment have on the frequency of:

- |                                    |                               |
|------------------------------------|-------------------------------|
| . 1 Lethal Mutations ?             | 2-P/T-1,2,3 2-IN-1 2-PL-1,2,3 |
| . 2 Conditional-Lethal Mutations ? | 2-P/T-1,2,3 2-IN-1 2-PL-1,2,3 |
| . 3 Nonlethal Mutations ?          | 2-P/T-1,2,3 2-IN-1 2-PL-1,2,3 |

If nonlethal mutations result from elements of the space environment, are they manifested as:

- |                                 |                                    |
|---------------------------------|------------------------------------|
| . 1 Structural abnormalities ?  | 2-IN-1 2-VB-2,3 2-PL-1,2,3 2-P/T-1 |
| . 2 Biochemical abnormalities ? | 2-IN-1 2-VB-2,3 2-PL-1,2,3 2-P/T-1 |
| . 3 Chromosomal abnormalities ? | 2-IN-1 2-VB-2,3 2-PL-1,2,3 2-P/T-1 |

### 2.1.4.2.2 Information Exchange

#### 2.1.4.2.2.1 Sexual Processes

What is the effect of the space environment on genetic information exchange through the processes of:

- |                   |         |
|-------------------|---------|
| . 1 Sexduction ?  | 2-P/T-1 |
| . 2 Conjugation ? | 2-P/T-1 |

#### 2.1.4.2.2.2 Epigenetic Systems

What is the effect of the space environment on genetic information exchange through epigenetic systems ?

2-IN-2 2-VB-2

#### 2.1.4.2.2.3 Asexual Processes

What is the effect of the space environment on genetic information exchange through the processes of:

- |                      |                    |
|----------------------|--------------------|
| . 1 Transduction ?   | 2-IN-2,3 2-P/T-2,3 |
| . 2 Transformation ? | 2-IN-2,3 2-P/T-2,3 |

#### 2.1.4.2.3 Information Storage

##### 2.1.4.2.3.1 What is the effect of the space environment on DNA?

If DNA is affected by the space environment, is the change manifested by:

.1 Induction?

2-IN-3 2-P/T-3

.2 Repression?

2-IN-3 2-P/T-3

##### 2.1.4.2.3.2 What is the effect of the space environment on RNA?

If RNA is affected by the space environment, do the effects arise from:

.1 Enzyme synthesis?

2-P/T-3

.2 Nucleotide synthesis?

2-P/T-3

#### 2.1.5 ORGANIZATION

##### 2.1.5.1 Physiological

##### 2.1.5.1.1 Nervous System

##### 2.1.5.1.1.1 Peripheral

##### 2.1.5.1.1.1.1 Sensory

What is the effect of the space environment on the:

.1 Exteroceptive nerves?

2-IN-1 2-VB-1,2,3

.2 Interoceptive nerves?

2-VB-1,2,3

.3 Proprioceptive nerves?

2-VB-1,2,3

#### 2.1.5.1.1.1.2 Effector

What is the effect of the space environment on the:

- |                                     |                 |
|-------------------------------------|-----------------|
| . 1 Neuromotor nerves?              | 2-IN-1 2-VB-2,3 |
| . 2 Sympathetic nervous system?     | 2-VB-2,3        |
| . 3 Parasympathetic nervous system? | 2-VB-2,3        |
| . 4 Secretory nerves?               | 2-VB-2,3        |

#### 2.1.5.1.1.2 Central Nervous System

##### 2.1.5.1.1.2.1 Spinal Nerves

What is the effect of the space environment on the:

- |   |          |
|---|----------|
| . 1 Reflex mechanisms?                      | 2-VB-2,3 |
| . 2 Conduction pathways?                    | 2-VB-2,3 |
| . 3 Facilitation and inhibition mechanisms? | 2-VB-2,3 |

##### 2.1.5.1.1.2.2 Brain

What is the effect of the space environment on the:

- |                                       |                 |
|---------------------------------------|-----------------|
| . 1 Motor control centers?            | 2-IN-1 2-VB-2,3 |
| . 2 Visceral control centers?         | 2-VB-2,3        |
| . 3 Centers associated with learning? | 2-VB-2,3        |
| . 4 Centers associated with memory?   | 2-VB-2,3        |
| . 5 Centers associated with emotion?  | 2-VB-2,3        |

#### 2.1.5.1.2 Musculo-Skeletal System

##### 2.1.5.1.2.1 Muscular System

##### 2.1.5.1.2.1.1 Voluntary Neural Control



#### 2.1.5.1.2.1.1.1 Striated Muscles

What is the effect of the space environment on:

- |   |        |          |
|---|--------|----------|
| . 1 Locomotion muscles?                             | 2-IN-2 | 2-VB-2,3 |
| . 2 Support muscles?                                | 2-IN-2 | 2-VB-2,3 |
| . 3 Muscles associated with the respiratory system? |        | 2-VB-2,3 |
| . 4 Muscles associated with organs?                 |        | 2-VB-2   |

#### 2.1.5.1.2.1.1.2 Voluntary Nonstriated Muscles

2-VB-2,3

What is the effect of the space environment on nonstriated muscles under voluntary control?

#### 2.1.5.1.2.1.2 Muscles Under Involuntary Control

##### 2.1.5.1.2.1.2.1 Striated Muscles

What is the effect of the space environment on:

- |   |          |
|---|----------|
| . 1 Cardiac muscle?                                 | 2-VB-2,3 |
| . 2 Muscles associated with the respiratory system? | 2-VB-2,3 |
| . 3 Muscles associated with temperature regulation? | 2-VB-2,3 |

##### 2.1.5.1.2.1.2.2 Nonstriated Involuntary Muscles

What is the effect of the space environment on the:

- |                               |        |
|-------------------------------|--------|
| . 1 Dermal muscles?           | 2-VB-2 |
| . 2 Vascular muscles?         | 2-VB-2 |
| . 3 Respiratory muscles?      | 2-VB-2 |
| . 4 Sphincteric muscles?      | 2-VB-2 |
| . 5 Gastrointestinal muscles? | 2-VB-2 |
| . 6 Urogenital muscles?       | 2-VB-2 |
| . 7 Glandular muscles?        | 2-VB-2 |

## 2.1.5.1.2.2 Musculo-Skeletal System

### 2.1.5.1.2.2.1 Locomotion

What is the effect of the space environment on:

- |                                   |                 |
|-----------------------------------|-----------------|
| . 1 Musculo-skeletal attachments? | 2-IN-2 2-VB-2,3 |
| . 2 Skeletal articulation?        | 2-IN-2 2-VB-2,3 |

### 2.1.5.1.2.2.2 Protection

What is the effect of the space environment on:

- |  |               |
|--|---------------|
| . 1 Skeletal protection of specific organs?    | 2-IN-2 2-VB-2 |
| . 2 Skeletal protection of general body areas? | 2-IN-2 2-VB-2 |

### 2.1.5.1.2.2.3 Support

What is the effect of the space environment on the response of skeletal support to:

- |                      |                          |
|----------------------|--------------------------|
| . 1 External stress? | 2-IN-1 2-VB-1 2-PL-1,2,3 |
| . 2 Internal stress? | 2-VB-1 2-PL-1,2,3        |
| . 3 Body shape?      | 2-VB-1 2-PL-1,2,3        |

## 2.1.5.1.3 Vascular System

### 2.1.5.1.3.1 Transport Processes

What is the effect of the space environment on the transport of:

- |                          |                     |
|--------------------------|---------------------|
| . 1 Organic nutrients?   | 2-VB-2,3 2-PL-1,2,3 |
| . 2 Inorganic nutrients? | 2-VB-2,3 2-PL-1,2,3 |

. 3 Respiratory gases?

If the transport of respiratory gases is affected, is the change manifested in the:

- |                               |        |          |
|-------------------------------|--------|----------|
| . 1 Respiratory pigments?     | 2-IN-2 | 2-VB-2,3 |
| . 2 Gas solubility?           |        | 2-VB-2,3 |
| . 4 Organic waste products?   |        | 2-VB-2,3 |
| . 5 Inorganic waste products? |        | 2-VB-2,3 |
| . 6 Hormones?                 |        | 2-VB-2,3 |

2.1.5.1.3.2 Homeostatic Processes

What is the effect of the space environment on:

. 1 Internal pressure:

If the internal pressure is affected, is the change manifested in the:

- |                                 |          |            |
|---------------------------------|----------|------------|
| . 1 Regulatory mechanisms?      | 2-IN-2   | 2-VB-2,3   |
| . 2 Cardiodynamics?             |          | 2-VB-2,3   |
| . 3 Hemodynamics?               |          | 2-VB-2,3   |
| . 4 Osmotic pressure?           | 2-IN-2   | 2-VB-2,3   |
| . 5 Active transport processes? | 2-IN-2,3 | 2-VB-2,3   |
| . 2 Extracellular fluids?       |          | 2-VB-1,2,3 |
| . 3 Extracellular electrolytes? |          | 2-VB-1,2,3 |
| . 4 Acid-base balance?          |          | 2-VB-1     |

If the acid-base balance is affected, is this change manifested by:

- |   |          |
|---|----------|
| . 1 A change in the carbon dioxide regulating system?           | 2-VB-2,3 |
| . 2 An alteration of the bioelectric properties of the protein? | 2-VB-2,3 |
| . 5 Heat exchange capacity?                                     |          |

If the heat exchange capacity is influenced, is the change manifested in:

- |                                     |          |
|-------------------------------------|----------|
| . 1 A conservation process?         | 2-VB-2,3 |
| . 2 A respiratory exchange process? | 2-VB-2,3 |
| . 3 A dermal exchange process?      | 2-VB-2,3 |

#### 2.1.5.1.4 Organ Systems

##### 2.1.5.1.4.1 Glandular

###### 2.1.5.1.4.1.1 Endocrine

What is the effect of the space environment on:

- . 1 Endocrine Hormones?

2-VB-2,3

###### 2.1.5.1.4.1.2 Exocrine

What is the effect of the space environment on:

- . 1 Enzyme systems?
- . 2 Lubricants?
- . 3 Heat exchange capacity?

2-VB-2,3

2-VB-2,3

2-VB-2,3

###### 2.1.5.1.4.2 Gastrointestinal Organs

What is the effect of the space environment on:

- . 1 Digestion of nutrients?
- . 2 Absorption of nutrients?

2-IN-2 2-VB-2,3

2-IN-2 2-VB-2,3

###### 2.1.5.1.4.3 Hepatic Organs

What is the effect of the space environment on:

- . 1 Metabolism?
- . 2 Detoxification processes?
- . 3 Storage processes?

2-VB-2,3

2-VB-2,3

2-VB-2,3

#### 2.1.5.1.4.4 Hemopoetic Organs

What is the effect of the space environment on the:

- . 1 Production of formed elements? 2-VB-2,3
- . 2 Storage capacity? 2-VB-2,3

#### 2.1.5.1.4.5 Reticuloendothelial Organs

What is the effect of the space environment on the:

- . 1 Immune mechanism? 2-VB-2,3
- . 2 Removal of foreign elements? 2-VB-2,3
- . 3 Formed elements? 2-VB-2,3

If the formed elements are influenced, is this change manifested in the:

- . 1 Production of these formed elements? 2-VB-2,3
- . 2 Removal of these formed elements? 2-VB-2,3

#### 2.1.5.1.4.6 Renal Organs

What is the effect of the space environment on the:

- . 1 Waste product removal process? 2-VB-2,3
- . 2 Acid-base balance? 2-VB-2,3
- . 3 Conservation of electrolytes? 2-VB-2,3
- . 4 Conservation of water? 2-VB-2,3

#### 2.1.5.1.4.7 Reproductive Organs

What is the effect of the space environment on:

- . 1 Oogenesis? 2-IN-2 2-VB-2,3
- . 2 Spermatogenesis? 2-IN-2 2-VB-2,3

2-IN-1 2-VB-2,3

#### 2.1.5.1.5.1 Senescence

#### 2.1.5.1.5.2 Life span

2-PL-1,2,3; 2-IN-1; 2-VB-2,3

## 2.1.5.2 Behavioral

### 2.1.5.2.1 Sensation

What is the effect of the space environment on:

- |                          |        |          |
|--------------------------|--------|----------|
| . 1 Cutaneous sensation? | 2-IN-1 | 2-VB-2,3 |
| . 2 Audition?            |        | 2-VB-2,3 |
| . 3 Taste?               |        | 2-VB-2,3 |
| . 4 Olfactory sensation? |        | 2-VB-2,3 |
| . 5 Vision?              |        |          |

If vision is influenced, is the change manifested in the sensation of:

- |                             |          |
|-----------------------------|----------|
| . 1 Brightness?             | 2-VB-2,3 |
| . 2 Acuity?                 | 2-VB-2,3 |
| . 3 Spatial relationships?  | 2-VB-2,3 |
| . 4 Temporal relationships? | 2-VB-2,3 |
| . 5 Motion?                 | 2-VB-2,3 |

### 2.1.5.2.2 Perception

What is the effect of the space environment on the perception of:

- |  |          |
|--|----------|
| . 1 Visual form?   | 2-VB-2,3 |
| . 2 Color?   |          |
| If color perception is affected, is the change manifested by an alteration in: |          |
| . 1 Contrast?  | 2-VB-2,3 |
| . 2 Field?   | 2-VB-2,3 |
| . 3 Adaptation?  | 2-VB-2,3 |
| . 3 Depth?   | 2-VB-2,3 |
| . 4 Time?  | 2-VB-2,3 |
| . 5 Sound?   | 2-VB-2,3 |

#### 2.1.5.2.3 Individual and Group Learning

What is the role of the following parameters on learning in the space environment:

- |    |                               |          |
|----|-------------------------------|----------|
| .1 | Conditioning?                 | 2-VB-2,3 |
| .2 | Discrimination?               | 2-VB-2,3 |
| .3 | Maze design?                  | 2-VB-2,3 |
| .4 | Shifts and span of attention? | 2-VB-2,3 |
| .5 | Association?                  | 2-VB-2,3 |
| .6 | Set effects?                  | 2-VB-2,3 |
| .7 | Transfer effects?             | 2-VB-2,3 |
| .8 | Reasoning?                    | 2-VB-2,3 |

#### 2.1.5.2.4 Memory

What is the effect of the space environment on:

- |    |               |          |
|----|---------------|----------|
| .1 | Interference? | 2-VB-2,3 |
| .2 | Recall?       | 2-VB-2,3 |
| .3 | Recognition?  | 2-VB-2,3 |
| .4 | Retention?    | 2-VB-2,3 |

#### 2.1.5.2.5 Individual and Group Motivation

What is the effect of the space environment on:

- |    |                                   |        |          |
|----|-----------------------------------|--------|----------|
| .1 | Drives?                           | 2-IN-1 | 2-VB-2,3 |
| .2 | Primary and secondary incentives? |        | 2-VB-2,3 |
| .3 | Nonorganic drives?                |        | 2-VB-2,3 |
| .4 | Learning?                         |        | 2-VB-2,3 |

#### 2.1.5.2.6 Emotion and Stress

##### 2.1.5.2.6.1 Neural Activation

What is the effect of the space environment on:

- .1 Central nervous system? 2-VB-2,3
- .2 Sympathetic and parasympathetic nervous system? 2-VB-2,3

##### 2.1.5.2.6.2 Other Bodily Changes

What is the effect of the space environment on:

- .1 Circulation? 2-VB-2,3
- .2 Muscular tension? 2-VB-2,3
- .3 Respiration? 2-VB-1,2,3

##### 2.1.5.2.6.3 Expressive Movements

What is the effect of the space environment on:

- .1 Facial expression? 2-VB-1
- .2 Vocal expression? 2-VB-1

#### 2.1.5.3 Host-Parasite Relationships

##### 2.1.5.3.1 Disease Transmission

###### 2.1.5.3.1.1 Aerosols

###### 2.1.5.3.1.1.1 Effect on Parasite

What is the effect of the space environment on:

- .1 Physical stability? 2-P/T-2
- .2 Rate of dissemination? 2-P/T-2
- .3 Longevity of aerosols of different-sized particles? 2-P/T-2
- .4 Viability of microbes in aerosols? 2-P/T-2



#### 2.1.5.3.1.1.2 Effect on host

What is the effect of the space environment on:

- .1 Aerosol pattern of penetration into respiratory tract? 2-P/T-2 2-VB-2
- .2 Lodgement of microbes in respiratory tract? 2-P/T-2 2-VB-2
- .3 Epidemiology
  - .1 Disease transmission for different numbers of animals per chamber? 2-IN-2 2-P/T-2 2-VB-2
  - .2 State of susceptibility or resistance? 2-IN-2 2-P/T-2 2-VB-2
  - .3 Disease transmission for different levels of confined space per animal? 2-IN-1 2-P/T-2 2-VB-2
  - .4 Number of microbes released by infected animal? 2-P/T-2 2-VB-2
  - .5 Type of aerosol produced? 2-P/T-2 2-VB-2
- .4 Course of Infection 2-P/T-2 2-VB-2

#### 2.1.5.3.2 Normal Flora

What is the effect of the space environment on:

- .1 Alterations, namely
  - .1 Quantitative alterations? 2-P/T-2
  - .2 Qualitative alterations? 2-P/T-2
  - .3 Selective factors for virulent agents? 2-P/T-3
  - .4 Protective functions? 2-P/T-3
- .2 Repopulation of gastrointestinal flora after chemotherapy? 2-P/T-2

#### 2.1.5.3.3 Immune Response

What is the effect of the space environment on:

- .1 Course of Response
  - .1 To vaccines? 2-VB-2 2-P/T-2
  - .2 To other antigens? 2-VB-2 2-P/T-2
- .2 Secretion of immune globulin A? 2-VB-3
- .3 Thymus function? 2-VB-3
- .4 Response and transformation of lymphocytes? 2-VB-3

- .5 Synthesis of immune globulin? 2-VB-3
- .6 Macrophage antigen processing? 2-VB-3 2-P/T-3
- .7 Degradation of immune mechanisms, namely
  - .1 Microbial shock on return to Earth? 2-VB-2 2-P/T-2
  - .2 Long-term inflight effect on susceptibility to infection? 2-VB-3 2-P/T-3
- .8 Local host defenses, namely
  - .1 Mucociliary function? 2-VB-3 2-P/T-3
  - .2 Phagocytic clearance? 2-VB-3 2-P/T-3
  - .3 Lysozyme concentration in secretions and blood? 2-VB-3 2-P/T-2
  - .4 Peristalsis? 2-VB-3 2-P/T-3

#### 2.1.5.3.4 Latent infections

What is the effect of the space environment on:

- .1 Factors that alter host defenses? 2-IN-3 2-VB-3 2-P/T-3
- .2 Factors that activate latent infections? 2-IN-3 2-VB-3 2-P/T-3

**APPENDIX C**  
**RESEARCH CLUSTER DESCRIPTIONS**

**SPACE BIOLOGY**

C-1

## Appendix C

### INTRODUCTION

This Appendix presents the research clusters identified by the study team of the Earth Orbital Experiment Program and Requirements Study. Each cluster, in general, consists of (1) a narrative synopsis; followed by (2) a list (by number and title) of the critical issues addressed by the research cluster; followed by (3) a crew activity matrix. The identification of these research clusters by number and title is given in Table C-1.

Table C1  
RESEARCH CLUSTERS

MANNED SPACEFLIGHT CAPABILITY

<u>Cluster No.</u>	<u>Title</u>
<u>BIOMEDICINE</u>	
1-BM-4*	Effects of Weightlessness on Circulatory Function
1-BM-5	Radiation, Toxicology, and Medical Problems
1-BM-6	Effects of Weightlessness on Stress Response
1-BM-7	Effects of Weightlessness on the Nervous System
1-BM-8	Effects of Weightlessness on Gastro-intestinal Function
1-BM-10	Body Fluid Analysis
1-BM-12	Studies on Instrumented Animals
1-BM-13	Effects of Weightlessness on Pulmonary Function
1-BM-14	Effects of Weightlessness on Metabolism
1-BM-15	Centrifuge Studies

BEHAVIORAL RESEARCH

1-BR-1	Sensory, Psychomotor, and Cognitive Behavior (5 parts)
1-BR-1-1	Visual Experiment
1-BR-1-2	Behavior Effects of Acoustic Environment
1-BR-1-3	Psychomotor
1-BR-1-4	Cognitive Capability
1-BR-1-5	Orientation
1-BR-2	Group Dynamics and Personal Adjustment

---

\*Missing numbers were assigned to clusters that were later combined with others or eliminated.

<u>Cluster No.</u>	<u>Title</u>
1-BR-3	Complex Task Behavior
1-BR-4	Skills Retention
1-BR-6	Performance Measurement

#### MAN-MACHINE RESEARCH

1-MM-1	Controls and Displays
1-MM-2	Locomotion and Restraint
1-MM-3	Habitability
1-MM-4	Work/Rest/Sleep Cycles
1-MM-5	Performance Aids

#### LIFE SUPPORT AND PROTECTIVE SYSTEMS

1-LS-1	Phase Change and Thermal Processes
1-LS-2	Material Transport Processes
1-LS-3	Atmosphere Supply Processes
1-LS-4	Water Management
1-LS-5	Water Electrolysis
1-LS-6	Food Management and Processes
1-LS-7	Atmosphere Purification Methods
1-LS-8	Life Support Monitoring and Control
1-LS-9	Waste Management
1-LS-10	Heat Transport Equipment
1-LS-11	Crew Equipment and Protective Systems
1-LS-12	Life Support System Maintenance and Repair

#### ENGINEERING EXPERIMENTS

1-EE-1	Data Management
1-EE-2	Structures
1-EE-3	Stabilization and Control (3 parts)

Cluster No.

Title

- 1-EE-3-1 Drift Measurement of Gyroscopic Attitude Controls
- 1-EE-3-2 Disturbance Torque Measurements
- 1-EE-3-3 Biowaste Electric Propulsion
- 1-EE-4      Navigation and Guidance (4 parts)
  - 1-EE-4-1 Onboard Laser Ranging
  - 1-EE-4-2 Interplanetary or Translunar Navigation By Spectroscopic Binary Satellite
  - 1-EE-4-3 Landmark Tracker Orbital Navigation
  - 1-EE-4-4 Navigation/Subsystem Candidate Evaluation
- 1-EE-5      Communications

OPERATIONS EXPERIMENTS

- 1-OE-1      Logistics and Resupply (2 parts)
  - 1-OE-1-1 Space Logistics and Resupply
  - 1-OE-1-2 Emergency and Rescue Operations
- 1-OE-2      Maintenance, Repair and Retrofit
- 1-OE-3      Assembly and Deployment
- 1-OE-4      Module Operations
- 1-OE-5      Vehicle Support Operations

SPACE BIOLOGY

VERTEBRATES

- 2-VB-1      Preliminary Investigations of Biological Processes, Using Primates and Small Vertebrates
- 2-VB-2      Intermediate Investigations of Biological Processes, Using Primates and Small Vertebrates
- 2-VB-3      Advanced Investigations of Biological Processes, Using Primates and Small Vertebrates

Cluster No.

Title

INVERTEBRATES

- |        |  |
|--------|--|
| 2-IN-1 | Preliminary Investigations of Biological Processes, Using Invertebrates  |
| 2-IN-2 | Intermediate Investigations of Biological Processes, Using Invertebrates |
| 2-IN-3 | Advanced Investigations of Biological Processes, Using Invertebrates     |

PROTISTS AND TISSUE CULTURES

- |         |   |
|---------|---|
| 2-P/T-1 | Preliminary Investigations of Biological Processes, Using Unicellular Specimens (protists and tissue cultures)  |
| 2-P/T-2 | Intermediate Investigations of Biological Processes, Using Unicellular Specimens (protists and tissue cultures) |
| 2-P/T-3 | Advanced Investigations of Biological Processes, Using Unicellular Specimens (protists and tissue cultures)     |

PLANTS

- |        |   |
|--------|---|
| 2-PL-1 | Preliminary Investigations of Biological Processes, Using Plants  |
| 2-PL-2 | Intermediate Investigations of Biological Processes, Using Plants |
| 2-PL-3 | Advanced Investigations of Biological Processes, Using Plants     |

SPACE ASTRONOMY

OPTICAL

- |      |   |
|------|---|
| 3-OW | Optical Structure of Small Extended Sources               |
| 3-OB | High-Resolution Planetary Optical Imagery                 |
| 3-OS | Optical (Faint Threshold) Surveys                         |
| 3-OP | High Precision Stellar Photometry                         |
| 3-SO | Optical Studies of the Solar Photosphere and Chromosphere |



<u>Cluster No.</u>	<u>Title</u>
--------------------	--------------

### X-RAY

3-XR	Precise Location, Size, and Structure of Known Discrete X-ray Sources, and Existence of Additional Unknown Sources
------	--

### LOW FREQUENCY RADIO

3-LF	Location and Properties of Discrete LF Radio Sources, and Structure and Properties of Diffuse Sources
------	---

### SPACE PHYSICS

#### PHYSICS AND CHEMISTRY LABORATORY

4-P/C-1	Effect of the Space Environment on Chemical Reactions
4-P/C-2	Shape and Stability of Liquid-Vapor Interfaces
4-P/C-3	Boiling and Convective Heat Transfer in Zero-G
4-P/C-4	Effect of Zero-Gravity on the Production of Controlled Density Materials
4-P/C-5	Effect of Electric and Magnetic Fields on Materials
4-P/C-6	The Use of Zero-Gravity to Produce Materials Having Superior Physical Characteristics
4-P/C-7	Improvements of Materials by Levitation Melting
4-P/C-8	Effect of Zero-Gravity on the Production of Films and Foils
4-P/C-9	Effects of Zero-G on Liquid Releases, Size Distribution of Liquid Drops
4-P/C-10	Capillary Flow in Zero-G
4-P/C-11	Behavior of Superfluids in the Weightless State

#### PLASMA PHYSICS LABORATORY

4-PP-1	Spacecraft Environment Interaction
4-PP-2	Energetic Particle Dynamics in the Magnetosphere (3 parts)

<u>Cluster No.</u>	<u>Title</u>
4-PP-2-1	Use of Alkali Metal Clouds as a Space Diagnostic
4-PP-2-2	Use of Electron Beams as a Space Diagnostic
4-PP-2-3	VLF Wave Propagation
4-PP-3	Thermal Plasma in the Ionosphere and Magnetosphere (3 parts)
4-PP-3-1	(Essentially the same as 4-PP-2-1)
4-PP-3-2	(Essentially the same as 4-PP-2-3)
4-PP-3-3	RF Plasma Resonance Studies
4-PP-4	Auroral Processes (3 parts)
4-PP-4-1	(Essentially the same as 4-PP-2-1)
4-PP-4-2	(Essentially the same as 4-PP-2-2)
4-PP-4-3	(Essentially the same as 4-PP-2-3)

#### COSMIC RAY LABORATORY

4-CR-1	Charge and Energy Spectra of Cosmic Ray Nuclear Component
4-CR-2	Energy Spectrum of High-Energy Primary Electrons and Positrons
4-CR-3	Energy Spectrum and Spatial Distribution of Primary Gamma Rays
4-CR-4	Long-Lived Heavy Isotopes in Cosmic Rays
4-CR-5	Antinuclei in Cosmic Rays
4-CR-6	Quarks (Stable Fractionally Charged Particles) in Cosmic Rays
4-CR-7	Unknown Particles in Cosmic Rays
4-CR-8	Characteristics of Albedo Particles Above 100 MeV
4-CR-9	Nucleon-Nucleon Cross-Sections at High Energies
4-CR-10	Spallation Cross-Sections at High Energies

<u>Cluster No.</u>	<u>Title</u>
--------------------	--------------

## COMMUNICATIONS AND NAVIGATION

### NOISE

5-N-1	Terrestrial Noise Measurements
-------	--------------------------------

5-N-2	Noise Source Identification
-------	-----------------------------

### PROPAGATION

5-P-1	Ionospheric Propagation Measurements
-------	--------------------------------------

5-P-2	Tropospheric Propagation Measurements
-------	---------------------------------------

5-P-3	Plasma Propagation Measurements
-------	---------------------------------

5-P-4	Multipath Measurements
-------	------------------------

### TEST FACILITIES

5-TF-1	Space Deployment and Calibration
--------	----------------------------------

5-TF-2	Demonstration and Test
--------	------------------------

### COMMUNICATIONS SYSTEMS

5-CS-1	MM Wave Demonstration
--------	-----------------------

5-CS-2	Optical Frequency Demonstration
--------	---------------------------------

### NAVIGATION SYSTEMS

5-NS-1	Satellite Navigation Techniques for Terrestrial Users
--------	---

5-NS-2	Laser Ranging
--------	---------------

5-NS-3	Autonomous Navigation Systems for Space
--------	---

5-NS-4	Surveillance Systems
--------	----------------------

5-NS-5	Collision Avoidance System Techniques
--------	---------------------------------------

5-NS-6	Search and Rescue Systems
--------	---------------------------

### EARTH OBSERVATIONS

### EARTH PHYSICS

6-EP-1	Photographic Coverage of the Earth
--------	------------------------------------

6-EP-2	Identification of Volcanic Activity
--------	-------------------------------------

Cluster No.

Title

AGRICULTURE, FOREST, AND RANGE RESOURCES

- 6-A/F-1 Crop Inventory and Land Use
- 6-A/F-2 Soil Type Mapping
- 6-A/F-3 Crop Identification
- 6-A/F-4 Crop Vigor and Yield Prediction
- 6-A/F-5 Wildfire Detection and Mapping

GEOGRAPHY, CARTOGRAPHY, AND CULTURAL RESOURCES

- 6-G/C-1 Photographic and Multisensor Mapping

GEOLOGY

- 6-G-1 Rock and Soil Type Identification
- 6-G-2 Use of Earth's Crust to Store and Condition  
Commodities or Waste
- 6-G-3 Geologic Disaster Avoidance
- 6-G-4 Utilization of Geothermal Energy Sources
- 6-G-5 Mineral and Oil Deposit Discovery
- 6-G-6 Identification of Land Forms and Structural Forms

HYDROLOGY AND WATER RESOURCES

- 6-H-1 Determination of Pollution in Water Resources
- 6-H-2 Flood Warning and Damage Assessment
- 6-H-3 Synoptic Inventory of Major Lakes and Reservoirs
- 6-H-4 Synoptic Inventory of Snow and Ice
- 6-H-5 Survey of Soil Moisture in Selected Areas of the  
North American Continent
- 6-H-6 Location of Underground Water Sources in  
Selected Areas
- 6-H-7 Survey of Hydrologic Features of Major River  
Basins

Cluster No.TitleOCEANOGRAPHY AND MARINE RESOURCES

- |       |   |
|-------|---|
| 6-O-1 | Ocean Pollution Identification, Measurement, and Effects    |
| 6-O-2 | Solar Energy Partition and Heating in the Sea Surface Layer |
| 6-O-3 | Ocean Population Dynamics and Fishery Resources             |
| 6-O-4 | Ocean Currents and Tide Forecasting                         |
| 6-O-5 | Ocean Physical Properties                                   |
| 6-O-6 | Ocean Solid Boundary Processes                              |
| 6-O-7 | Ocean Surface Activity Forecasting                          |

METEOROLOGY

- |       |  |
|-------|--|
| 6-M-1 | Determination of Boundary Layer Exchange Processes Using IR Radiometry |
| 6-M-2 | UHF Sferics Detection  |
| 6-M-3 | Atmosphere Density Measurements by Stellar Occultation                 |
| 6-M-4 | Zero-G Environment Cloud Physics Experiment                            |
| 6-M-5 | Detection and Monitoring of Atmospheric Pollutants                     |
| 6-M-6 | Support of Studies of Special Geographical Areas                       |

**EARTH ORBITAL EXPERIMENT PROGRAM  
AND REQUIREMENTS STUDY**

**SPACE BIOLOGY**

**RESEARCH CLUSTER-2-VB-1  
PRELIMINARY INVESTIGATIONS OF BIOLOGICAL PROCESSES,  
USING PRIMATES AND SMALL VERTEBRATES**

*C-2-1*

RESEARCH CLUSTER SYNOPSIS-SPACE BIOLOGY  
2-VB-1

Preliminary Investigations of Biological Processes,  
Using Primates and Small Vertebrates

1. Research Objectives

Dividing the Space Biology Research Program into specimen-oriented research clusters permits a large number of specific research objectives to be undertaken within a particular research cluster. The present research cluster, which is oriented toward an investigation of biological processes in vertebrates, includes experiments on metabolism, geosensitivity, activity cycles and rhythms, reproductive activities, physiological functions, life span and aging, anatomical and histological changes, and individual and group behavior. As a consequence of this broad spectrum of research activities, the research cluster is more properly identified with Broad Objectives rather than Supporting Specific Objectives. The NASA-defined Scientific and Technological Objectives in Space Biology to which experiments on primates and small vertebrates may be expected to contribute are:

1. To understand the role of gravity in life processes and the capability of living organisms to adapt to gravitational changes.
2. To understand the role of time in biology, including the effects of time-varying environmental parameters on biological rhythms and aging.

The critical issues related to the objectives of this research cluster are most easily referable to the three-dimensional matrix from which the various issues were derived (Chart 2-1, Appendix A). The taxonomy axis is, by nature of this research division, restricted to the vertebrates. The environment axis will be restricted, through experimental controls, to the effects of zero-g. On the third axis, all life processes are potential research candidates and will be examined at least partially. The vertebrate research program therefore is responsive to all identified critical issues down to the levels at which research on nonvertebrate forms is indicated.

The specific experiment objective associated with the research cluster is the observation of alterations caused by the lack of gravity in vertebrate behavior, physiology, reproduction, response to stimuli, and host-parasite relationships.

## 2. Background and Current Status

Many of the physiological changes observed on the Mercury and Gemini flights were anticipated from the results of ground-based research on human subjects involved in prolonged bed-rest and water-immersion studies. Such experimental techniques are not readily adaptable to animal subjects, and consequently, most information must come directly from spaceflight data. Very early in the space program the only information available on living subjects was derived from suborbital and short orbital flights of experimental animals. These succeeded in their primary purpose of demonstrating that no catastrophic consequences would result from brief exposure to weightlessness, but they did little to reveal the nature of the more chronic physiological changes. Enthusiastic and widespread interest has been evidenced in the scientific community for continued research in space biology, both to reveal potential problems in manned spaceflight and to increase knowledge concerning basic biological processes. This interest is manifested in the design and development of a space-qualifiable rodent-research facility by Dr. V.P. Meehan at the University of Southern California; by the design and construction of a prototype unrestrained primate space-research facility (orbiting primate experiment) by NASA-OART; by the thorough study of the requirements of an orbiting primate laboratory by Dr. N. Pace at the University of California, Berkeley; and by the various primate and small vertebrate animal space experiments and experimental techniques developed at numerous government and university laboratories throughout the country.

Considerable information was derived from the Biosatellite III Primate Experiment, but much additional research is necessary to verify the findings and to further investigate many of the problems that this flight revealed. The only vertebrate experiment scheduled for Skylab A, is Circadian Rhythm in Pocket Mice S-071. The results of this experiment should give interesting information about the role of weightlessness and various aspects of the Earth's environment on animal cyclical activities.

## 3. Description of Research

Experiments investigating biological processes in primates and small vertebrates in the space environment potentially include a large number and variety of observations ranging from simple TV monitoring of activities to extremely sophisticated studies on enzyme activities in metabolic pathways.



The sequencing of experiments is based on both science and expediency. The common scientific approach of initial general observations, followed by more complete examination of aspects that show alterations, and concluding in detailed studies of mechanisms is quite logical in Space Biology. Recognition of the limitations of crew size, available time, and specialized skills in early spaceflight also leads to the design of experiments which at first require minimal crew involvement, next moderate involvement, and later extensive crew involvement. These two approaches are quite compatible and are readily combined in the program definition.

The preliminary phase (Phase I), Research Cluster 2-VB-1, of the vertebrate experiment program will consist of research requiring very little experimenter participation and consisting of rather general observations. Included in this phase are experiments recommended for inclusion in the Skylab B and Early Space Station programs. These experiments involve the establishment of an experimental mouse colony and an automated primate laboratory. Measurements and observations will include food and water intake, locomotion, mating behavior, activity cycles and parent-offspring behavior in the mice; and ECG, blood pressure,  $Pa_{O_2}$ , blood temperature, fluid and electrolytic balance and metabolic balance in the primates. The only crew participation required will be associated with a daily general inspection of the animals and the removal and preservation of dead or dying subjects, the preparation of the subjects for reentry and return. The crew will also be responsible for separation and compartmentation of mice born in space (when they become 2 weeks old) for use in development of new zero-g colonies. These experiments are designated 3 - 102 and 3 - 103 in Skylab B, and 3 - 208 and 3 - 212 in slightly advanced versions for the Early Space Station; they are detailed in Phase II of A Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA CR 111794, and summarized in Appendix H of the present study. Skylab A, Experiment S-071, Circadian Rhythm in Pocket Mice, is also recommended for verification during the Early Space Station program.

Experiments conducted during the intermediate phase (Phase II), Research Cluster 2-VB-2, which is characterized by research on previously observed changes and increased experimenter participation, are exemplified by the experiments recommended for Mid Space Station in the previously referenced Biotechnology Laboratory Study. These experiments include behavioral studies on primates and rats, designated 3-128 and 3-239; reproductive studies with mice, 3-229; physiological studies on rats and primates and

marmot CNS activity during hibernation, 3-232, 3-235, and 3-236; biorhythms in mice, 3-221; and the course of bacterial and viral infections in mice, microflora identification in primates, and immune responses of rats, 3-242, 3-243, and 3-244. A significant increase in crew activity is associated with these experiments, primarily involving laboratory analysis: blood sampling, blood and urine analysis, dissections and autopsies with examinations for histopathological anomalies, and body and organ weights (masses). Microbiological analyses will include microflora identification, serologic reactions, and antibody concentrations. Research during the intermediate phase will require the participation of laboratory specialists. The personnel should be trained and experienced biological scientists (technologists) who are also trained as astronauts. The full-time participation of two such individuals should be anticipated in this phase of the Space Biology program.

Experiments during the advanced phase of this research (Phase III), Research Cluster 2-VB-3, will be directed toward the investigation of mechanisms. The experiment techniques will be sophisticated, and extensive experimenter participation will be required. Insofar as changes cannot as yet be predicted, no specific experiments can be assumed for determining the mechanisms. Regardless of their individual details, the experiments will undoubtedly involve studies at the subcellular level, including investigations of metabolic pathways and transport mechanisms. The general technique employed in such studies involves the use of radioactive and heavy or light isotopes as tracer atoms. Molecules of interest are tagged in the desired positions by the tracer atoms (normally performed pre-flight), the molecules are metabolized, the by-products are identified from the tags, and their characteristics are related to the nature of the pathway. The study of metabolic pathways and transport mechanisms requires advanced instrumentation, complex and precise techniques, and fully experienced investigators. It would be desirable to have the principal investigator onboard to conduct the experiments; in his absence, a highly qualified scientist with experience in the specific field should conduct them. He should be assisted by at least two experienced technologists. The duties of the team should be essentially restricted to space biology research.

#### 4. Impact on Spacecraft

The major impact of experiments conducted during the preliminary phase will come from the experimental modules. The mouse module and the primate module will both be self-contained with their own environmental-control, waste-management, and food and

water dispensing systems; TV cameras; and recording electronics. The spacecraft systems will be used only for data management, including the display, recording, and storage of information transmitted from the modules. The mouse module is expected to weigh 400 lb, occupy 30 cu ft, and require about 80 w for 12 hr per day (light) and 20 w for 12 hr per day (dark), plus 30 w during video recording. The primate module is expected to weigh 900 lb, occupy 110 cu ft, and require 130 w for 12 hr per day (light) and 30 w for 12 hr per day (dark), plus 30 w during video recording. The spacecraft system will be required to furnish oxygen and other gases needed for replenishment by the module life-support systems.

As mentioned earlier, required crew time will be minimal, consisting primarily of routine inspections and preparation of the modules for return to Earth at the end of the mission. Additional time will be required (1 to 2 hr) at intervals for the sex identification and separation of young mice.

The intermediate-phase research will continue to require self-contained modules for the experimental subjects, the number being related to the number of experiments that can be accommodated on a specific mission. Certain laboratory facilities will also be required. Blood and urine may be analyzed in the biomedical clinical chemistry laboratory; a single microbiology laboratory serving various ship's functions will suffice for the required microbiological analyses; but animal dissection, autopsy, and histopathological examinations will require space and facilities not required by other experimental disciplines. These will include an automatic tissue processor and staining system, vacuum infiltration oven, microtome, and compound microscope with built-in automatic camera. Increased crew time will be required for the laboratory procedures, which will probably be performed by specialists in space biology.

Experiments conducted during the advanced phase (Phase III) will continue to require modules for experimental animals although the requirements will be increased to include a completed separate laboratory for studies in cellular metabolism, membrane phenomena, and transport systems. Facilities should be sufficient to permit onboard utilization of all advanced techniques.

5. Required Supporting Technology Development

The development, design, construction, and testing of the experimental modules is the major area of required research and technology. A number of subsystems must be designed and integrated for the proper functioning of the module. This work is already in progress under the direction of Dr. Meehan, USC, and Dr. Pace, UC Berkeley. Laboratory equipment required for intermediate phase studies is planned for IMBLMS, with the exception of that required for histological and histopathological examinations. Development, testing, and integration of these items are needed. Advanced phase research is almost totally in the area of STD. Conceptual studies must be undertaken to prescribe programs and techniques, followed by the identification and design of equipment. Studies must be undertaken in all cases to properly integrate the laboratories into the overall Space Research Facility design.

6. References

1. Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions. MDC G0620.
2. W.R. Adey. Biosatellite III: Preliminary Findings, Science 166, October 24, 1969, pp. 492-95.

PRELIMINARY INVESTIGATIONS OF BIOLOGICAL PROCESSES,  
USING PRIMATES AND SMALL VERTEBRATES

2-VB-1

Critical Issues Addressed by Research Cluster

2.1.1.1.1.1.4

What is the effect of the space environment of the biosynthesis of glycogen?

2.1.1.1.1.1.7

What is the effect of the space environment on the biosynthesis of polysaccharides?

2.1.1.1.2.2.1.1

What is the effect of the space environment on the anabolism of calcium?

2.1.1.1.2.2.1.2

What is the effect of the space environment on the anabolism of phosphorus?

2.1.1.1.2.2.1.3

What is the effect of the space environment on the anabolism of other skeletal minerals?

2.1.2.1.1

What is the effect of the space environment on aerobic mechanisms?

2.1.3.1.1

What is the effect of the space environment on geotropic response?

2.1.3.2.1.1

What is the effect of the space environment on circadian rhythms, as manifested by organism activity?

2.1.3.2.1.2

What is the effect of the space environment on circadian rhythms, as manifested by feeding.

2.1.3.2.5.2

What is the effect of the space environment on circadian rhythms, as manifested by hibernation (depressed metabolism/hypothermia)?

2.1.4.1.1.1.1

What is the effect of the space environment on fertilization?

2.1.4.1.1.1.2

What is the effect of the space environment on cleavage?

2.1.4.1.1.1.3.1.1

What is the effect of the space environment on the development of the ectoderm?

2.1.4.1.1.1.3.1.2

What is the effect of the space environment on the development of the presumptive epidermis?

2.1.4.1.1.1.3.1.3

What is the effect of the space environment on the development of the neural plate?

2.1.4.1.1.1.3.1.4

What is the effect of the space environment on the development of the advanced ectodermal derivatives?

2.1.4.1.1.1.3.2.1

What is the effect of the space environment on the development of the mesoderm?

2.1.4.1.1.1.3.2.2

What is the effect of the space environment on the development of the chorda?

2.1.4.1.1.1.3.2.3

What is the effect of the space environment on the development of the somites?

2.1.4.1.1.1.3.2.4

What is the effect of the space environment on the development of the nephrotome?

2.1.4.1.1.1.3.2.5

What is the effect of the space environment on the development of the lateral plate?

2.1.4.1.1.1.3.2.6

What is the effect of the space environment on the development of the advanced mesodermal derivatives?

2.1.4.1.1.1.3.3.1

What is the effect of the space environment on the development of the endoderm?

2.1.4.1.1.1.3.3.2

What is the effect of the space environment on the development of the advanced endodermal derivatives?

2.1.4.1.1.1.3.4

What is the effect of the space environment on transformation?

2.1.5.1.1.1.1.1

What is the effect of the space environment on the exteroceptive nerves?

2.1.5.1.1.1.1.2

What is the effect of the space environment on the interoceptive nerves?

2.1.5.1.1.1.1.3

What is the effect of the space environment on the proprioceptive nerves?

2.1.5.1.2.2.3.1

What is the effect of the space environment on the response of skeletal support to external stress?

2.1.5.1.2.2.3.2

What is the effect of the space environment on the response of skeletal support to internal stress?

2.1.5.1.2.2.3.3

What is the effect of the space environment on the response of skeletal support to body shape?

2.1.5.1.3.2.2

What is the effect of the space environment on extracellular fluids?

2.1.5.1.3.2.3

What is the effect of the space environment on extracellular electrolytes?

2.1.5.1.3.2.4

What is the effect of the space environment on acid-base balance?

2.1.5.2.6.2.3

What is the effect of the space environment on respiration?

2.1.5.2.6.3.1

What is the effect of the space environment on facial expression?

2.1.5.2.6.3.2

What is the effect of the space environment on vocal expression?

**EARTH ORBITAL EXPERIMENT PROGRAM  
AND REQUIREMENTS STUDY**

**SPACE BIOLOGY**

**RESEARCH CLUSTER-2-VB-2  
INTERMEDIATE INVESTIGATIONS OF BIOLOGICAL PROCESSES,  
USING PRIMATES AND SMALL VERTEBRATES**

*C-2-10*



INTERMEDIATE INVESTIGATIONS OF BIOLOGICAL  
PROCESSES, USING PRIMATES AND SMALL VERTEBRATES

2-VB-2

Critical Issues Addressed by Research Cluster

- 2.1.1.1.1.4  
What is the effect of the space environment on the biosynthesis of glycogen?
- 2.1.1.1.1.7  
What is the effect of the space environment on the biosynthesis of other polysaccharides?
- 2.1.1.1.2.1  
What is the effect of the space environment on the biosynthesis of creatine phosphate?
- 2.1.1.1.3.1  
What is the effect of the space environment on the biosynthesis of acetyl coenzyme-A?
- 2.1.1.1.2.2.1.1  
What is the effect of the space environment on the anabolism of calcium?
- 2.1.1.1.2.2.1.2  
What is the effect of the space environment on the anabolism of phosphorus?
- 2.1.1.1.2.2.1.3  
What is the effect of the space environment on the anabolism of other skeletal minerals?
- 2.1.1.1.2.2.2.1  
What is the effect of the space environment on the anabolism of sodium?
- 2.1.1.1.2.2.2.2  
What is the effect of the space environment on the anabolism of potassium?
- 2.1.1.1.2.2.2.3  
What is the effect of the space environment on the anabolism of chloride?
- 2.1.1.1.2.2.2.4  
What is the effect of the space environment on the anabolism of other nonskeletal minerals?

2. 1. 1. 1. 2. 3. 1

What is the effect of the space environment on the biosynthesis of muscle protein?

2. 1. 1. 1. 2. 3. 2

What is the effect of the space environment on the biosynthesis of collagen?

2. 1. 1. 1. 2. 3. 3

What is the effect of the space environment on the biosynthesis of other proteins?

2. 1. 1. 1. 3. 1. 2. 1

What is the effect of the space environment on the biosynthesis of thyroid hormones?

2. 1. 1. 1. 3. 1. 2. 2

What is the effect of the space environment on the biosynthesis of parathyroid hormones?

2. 1. 1. 1. 3. 1. 2. 3

What is the effect of the space environment on the biosynthesis of gonadal hormones?

2. 1. 1. 1. 3. 1. 2. 4

What is the effect of the space environment on the biosynthesis of adrenal cortical hormones?

2. 1. 1. 1. 3. 1. 2. 5

What is the effect of the space environment on the biosynthesis of adrenal medulla hormones?

2. 1. 1. 1. 3. 1. 2. 6

What is the effect of the space environment on the biosynthesis of pancreatic hormones?

2. 1. 1. 1. 3. 1. 2. 7

What is the effect of the space environment on the biosynthesis of other hormones?

2. 1. 1. 1. 3. 2. 1. 1. 1

What is the effect of the space environment on the biosynthesis of ATP?

2. 1. 1. 1. 3. 2. 1. 1. 2

What is the effect of the space environment on the biosynthesis of UTP?

2. 1. 1. 1. 3. 2. 1. 1. 3

What is the effect of the space environment on the biosynthesis of GTP?

2. 1. 1. 1. 3. 2. 1. 1. 4

What is the effect of the space environment on the biosynthesis of nucleotides?

2. 1. 1. 1. 3. 2. 1. 2

What is the effect of the space environment on the biosynthesis of DNA?

2. 1. 1. 1. 3. 2. 1. 3. 1

What is the effect of the space environment on the biosynthesis of messenger RNA?

2. 1. 1. 1. 3. 2. 1. 3. 2

What is the effect of the space environment on the biosynthesis of transfer RNA?

2. 1. 1. 1. 3. 2. 1. 3. 3

What is the effect of the space environment on the biosynthesis of ribosomal RNA?

2. 1. 1. 1. 3. 2. 1. 3. 4

What is the effect of the space environment on the biosynthesis of other RNA s?

2. 1. 1. 1. 3. 2. 2

What is the effect of the space environment on the biosynthesis of histones?

2. 1. 1. 1. 3. 3. 1

What is the effect of the space environment on the biosynthesis of coenzyme-A?

2. 1. 1. 1. 3. 3. 2

What is the effect of the space environment on the biosynthesis of flavins?

2. 1. 1. 1. 3. 3. 3

What is the effect of the space environment on the biosynthesis of biotin?

2. 1. 1. 1. 3. 3. 4

What is the effect of the space environment on the biosynthesis of nicotinic acid?

2. 1. 1. 1. 3. 3. 5

What is the effect of the space environment on the biosynthesis of folic acid?

2. 1. 1. 1. 3. 3. 6

What is the effect of the space environment on the biosynthesis of cobamide coenzyme?

2.1.1.1.3.3.7

What is the effect of the space environment on the biosynthesis of thiamine cocarboxylase?

2.1.1.1.3.3.8

What is the effect of the space environment on the biosynthesis of other enzyme cofactors?

2.1.1.2.1.2.1

What is the effect of the space environment on the metabolic control functions of thyroid hormones?

2.1.1.2.1.2.2

What is the effect of the space environment on the metabolic control functions of parathyroid hormones?

2.1.1.2.1.2.3

What is the effect of the space environment on the metabolic control functions of gonadal hormones?

2.1.1.2.1.2.4

What is the effect of the space environment on the metabolic control functions of adrenal cortical hormones?

2.1.1.2.1.2.5

What is the effect of the space environment on the metabolic control functions of adrenal medulla hormones?

2.1.1.2.1.2.6

What is the effect of the space environment on the metabolic control functions of pancreatic hormones?

2.1.1.2.1.2.7

What is the effect of the space environment on the metabolic control functions of adenohipophyseal hormones?

2.1.1.2.1.2.8

What is the effect of the space environment on the metabolic control functions of neurohypophyseal hormones?

2.1.1.2.1.2.9

What is the effect of the space environment on the metabolic control functions of other hormones?

2.1.1.3.1.1.1

What is the effect of the space environment on the breakdown of ATP?

2.1.1.3.1.1.2

What is the effect of the space environment on the breakdown of UTP?

2. 1. 1. 3. 1. 1. 3

What is the effect of the space environment on the breakdown of ITP?

2. 1. 1. 3. 1. 1. 4

What is the effect of the space environment on the breakdown of GTP?

2. 1. 1. 3. 1. 2

What is the effect of the space environment on the breakdown of adenosine?

2. 1. 1. 3. 1. 2. 2

What is the effect of the space environment on the breakdown of cytidine?

2. 1. 1. 3. 1. 3

What is the effect of the space environment on the breakdown of inosine?

2. 1. 1. 3. 1. 4

What is the effect of the space environment on the breakdown of guanosine?

2. 1. 1. 3. 1. 3. 1. 1

What is the effect of the space environment on the breakdown of adenine?

2. 1. 1. 3. 1. 3. 1. 2

What is the effect of the space environment on the breakdown of hypoxanthine?

2. 1. 1. 3. 1. 3. 1. 3

What is the effect of the space environment on the breakdown of xanthine?

2. 1. 1. 3. 1. 3. 1. 4

What is the effect of the space environment on the breakdown of **guanine**?

2. 1. 1. 3. 1. 3. 2. 1

What is the effect of the space environment on the breakdown of uracil?

2. 1. 1. 3. 1. 3. 2. 2

What is the effect of the space environment on the breakdown of cytosine?

2. 1. 1. 3. 1. 3. 2. 3

What is the effect of the space environment on the breakdown of thymine?

2.1.1.3.1.4.1

What is the effect of the space environment on the breakdown of ribose?

2.1.1.3.1.4.2

What is the effect of the space environment on the breakdown of deoxyribose?

2.1.1.3.2.1

What is the effect of the space environment on glycolytic processes?

2.1.1.3.2.2

What is the effect of the space environment on amino acid pools?

2.1.1.3.2.3

What is the effect of the space environment on ketogenic processes?

2.1.1.3.3.1.1

What is the effect of the space environment on beta-oxidation of fatty acids?

2.1.1.3.3.1.2

What is the effect of the space environment on omega-oxidation of fatty acids?

2.1.1.3.3.2

What is the effect of the space environment on the catabolism of triglycerides?

2.1.1.3.4.1.1

What is the effect of the space environment on carbohydrate catabolism through the pentose phosphate shunt?

2.1.1.3.4.1.2

What is the effect of the space environment on carbohydrate catabolism through the TCA cycle?

2.1.1.3.4.2.1

What is the effect of the space environment on carbohydrate catabolism through the glycolytic mechanisms?

2.1.1.3.4.2.2

What is the effect of the space environment on carbohydrate catabolism through the nonglycolytic mechanisms?

2.1.2.1.1.1.1

What is the effect of the space environment on the reaction mediated by the enzyme, pyruvic oxidase?

2. 1. 2. 1. 1. 1. 2

What is the effect of the space environment on the reaction mediated by the isocitric enzyme?

2. 1. 2. 1. 1. 1. 3

What is the effect of the space environment on the reaction mediated by the enzyme, alpha ketoglutarate oxidase?

2. 1. 2. 1. 1. 1. 4

What is the effect of the space environment on the reaction mediated by the enzyme, succinyl thiokinase?

2. 1. 2. 1. 1. 1. 5

What is the effect of the space environment on the reaction mediated by the enzyme, succinic dehydrogenase?

2. 1. 2. 1. 1. 1. 6

What is the effect of the space environment on the reaction mediated by the enzyme, malic dehydrogenase?

2. 1. 2. 1. 1. 2. 1

What is the effect of the space environment on the formation of ATP at the NAD/FAC crossover point?

2. 1. 2. 1. 1. 2. 2

What is the effect of the space environment on the formation of ATP at the FAD/cytochrome C crossover point?

2. 1. 2. 1. 1. 2. 3

What is the effect of the space environment on the formation of ATP at the cytochrome C/cytochrome oxidase crossover point?

2. 1. 2. 1. 1. 3. 1

What is the effect of the space environment on the reaction mediated by the enzyme, glucose-6-phosphate dehydrogenase?

2. 1. 2. 1. 1. 3. 2

What is the effect of the space environment on the reaction mediated by the enzyme, 6-phospho gluconic acid dehydrogenase?

2. 1. 2. 1. 1. 4. 1

What is the effect of the space environment on the reaction mediated by the enzyme, acyl dehydrogenase?

2. 1. 2. 1. 1. 4. 2

What is the effect of the space environment on the reaction mediated by the enzyme, hydroxyacyl dehydrogenase?

2.1.2.1.1.5.1

What is the effect of the space environment on the reaction mediated by glutamic acid dehydrogenase?

2.1.2.1.1.6.1

What is the effect of the space environment on the reactions mediated by the transaminases?

2.1.2.1.2.1.1

What is the effect of the space environment on the glycolitic reaction mediated by the enzyme, phosphoglyceraldehyde dehydrogenase?

2.1.2.1.2.1.2

What is the effect of the space environment on the glycolitic reaction mediated by the enzyme, phosphoglycerol kinase?

2.1.2.1.2.1.3

What is the effect of the space environment on the glycolitic reaction mediated by the enzyme, pyruvic oxidase?

2.1.3.2.1.1

What is the effect of the space environment on circadian rhythms, as manifested by organism activity?

2.1.3.2.1.2

What is the effect of the space environment on circadian rhythms, as manifested by feeding?

2.1.3.2.1.12

What is the effect of the space environment on circadian rhythms, as manifested by excretion of urinary constituents?

2.1.3.2.5.2

What is the effect of the space environment on circadian rhythms, as manifested by hibernation (depressed metabolism/hypothermia)?

2.1.3.2.7.2.1

What is the effect of the space environment on metabolic and/or energetic alterations of rhythm resulting from nuclear control?

2.1.3.2.7.2.2

What is the effect of the space environment on metabolic and/or energetic alterations of rhythm resulting from oscillations in membrane properties?



2. 1. 4. 1. 1. 1. 1

What is the effect of the space environment on fertilization?

2. 1. 4. 1. 1. 1. 2

What is the effect of the space environment on cleavage?

2. 1. 4. 1. 1. 1. 3

What is the effect of the space environment on differentiation?

2. 1. 4. 2. 1. 3. 1

What is the effect of the space environment on nonlethal mutations manifested as structural abnormalities.

2. 1. 4. 2. 1. 3. 2

What is the effect of the space environment on nonlethal mutations manifested as biochemical abnormalities?

2. 1. 4. 2. 1. 3. 3

What is the effect of the space environment on nonlethal mutations manifested as chromosomal abnormalities?

2. 1. 4. 2. 2. 2

What is the effect of the space environment on genetic information exchange through epigenetic systems?

2. 1. 5. 1. 1. 1. 1. 1

What is the effect of the space environment on the exteroceptive nerves?

2. 1. 5. 1. 1. 1. 1. 2

What is the effect of the space environment on the interoceptive nerves?

2. 1. 5. 1. 1. 1. 1. 3

What is the effect of the space environment on the proprioceptive nerves?

2. 1. 5. 1. 1. 1. 2. 1

What is the effect of the space environment on the neuromotor nerves?

2. 1. 5. 1. 1. 1. 2. 2

What is the effect of the space environment on the sympathetic nervous system?

2. 1. 5. 1. 1. 1. 2. 3

What is the effect of the space environment on the parasympathetic nervous system?

2. 1. 5. 1. 1. 1. 2. 4

What is the effect of the space environment on the secretory nerves?

2. 1. 5. 1. 1. 2. 1. 1

What is the effect of the space environment on the reflex mechanisms?

2. 1. 5. 1. 1. 2. 1. 2

What is the effect of the space environment on the conduction pathways?

2. 1. 5. 1. 1. 2. 1. 3

What is the effect of the space environment on the facilitation and inhibition mechanisms?

2. 1. 5. 1. 1. 2. 2. 1

What is the effect of the space environment on the motor control centers?

2. 1. 5. 1. 1. 2. 2. 2

What is the effect of the space environment on the visceral control centers?

2. 1. 5. 1. 1. 2. 2. 3

What is the effect of the space environment on the centers associated with learning?

2. 1. 5. 1. 1. 2. 2. 4

What is the effect of the space environment on the centers associated with memory?

2. 1. 5. 1. 1. 2. 2. 5

What is the effect of the space environment on the centers associated with emotion?

2. 1. 5. 1. 2. 1. 1. 1. 1

What is the effect of the space environment on the locomotion muscles?

2. 1. 5. 1. 2. 1. 1. 1. 2

What is the effect of the space environment on the support muscles?

2. 1. 5. 1. 2. 1. 1. 1. 3

What is the effect of the space environment on the muscles associated with the respiratory system?

2. 1. 5. 1. 2. 1. 1. 1. 4

What is the effect of the space environment on the muscles associated with organs?

2. 1. 5. 1. 2. 1. 1. 2

What is the effect of the space environment on nonstriated muscles under voluntary control?

2. 1. 5. 1. 2. 1. 2. 1. 1

What is the effect of the space environment on the cardiac muscle?

2. 1. 5. 1. 2. 1. 2. 1. 2

What is the effect of the space environment on the muscles associated with the respiratory system?

2. 1. 5. 1. 2. 1. 2. 1. 3

What is the effect of the space environment on the muscles associated with temperature regulation?

2. 1. 5. 1. 2. 1. 2. 2. 1

What is the effect of the space environment on the dermal muscles?

2. 1. 5. 1. 2. 1. 2. 2. 2

What is the effect of the space environment on the vascular muscles?

2. 1. 5. 1. 2. 1. 2. 2. 3

What is the effect of the space environment on the respiratory muscles?

2. 1. 5. 1. 2. 1. 2. 2. 4

What is the effect of the space environment on the sphincteric muscles?

2. 1. 5. 1. 2. 1. 2. 2. 5

What is the effect of the space environment on the gastrointestinal muscles?

2. 1. 5. 1. 2. 1. 2. 2. 6

What is the effect of the space environment on the urogenital muscles?

2. 1. 5. 1. 2. 1. 2. 2. 7

What is the effect of the space environment on the glandular muscles?

2. 1. 5. 1. 2. 2. 1. 1

What is the effect of the space environment on the musculoskeletal attachments?

2. 1. 5. 1. 2. 2. 1. 2

What is the effect of the space environment on the skeletal articulation?

2.1.5.1.2.2.1

What is the effect of the space environment on the skeletal protection of specific organs?

2.1.5.1.2.2.2

What is the effect of the space environment on the skeletal protection of general body areas?

2.1.5.1.3.1.1

What is the effect of the space environment on the transport of organic nutrients?

2.1.5.1.3.1.2

What is the effect of the space environment on the transport of inorganic nutrients?

2.1.5.1.3.1.3.1

What is the effect of the space environment on the transport of respiratory pigments?

2.1.5.1.3.1.3.2

What is the effect of the space environment on gas solubility?

2.1.5.1.3.1.4

What is the effect of the space environment on the organic waste products?

2.1.5.1.3.1.5

What is the effect of the space environment on the inorganic waste products?

2.1.5.1.3.1.6

What is the effect of the space environment on the transportation of hormones?

2.1.5.1.3.2.1.1

What is the effect of the space environment on the internal pressure manifested in the regulatory mechanisms?

2.1.5.1.3.2.1.2

What is the effect of the space environment on the internal pressure manifested in the cardiodynamics?

2.1.5.1.3.2.1.3

What is the effect of the space environment on the internal pressure manifested in the hemodynamics?

2.1.5.1.3.2.1.4

What is the effect of the space environment on the internal pressure manifested in the osmotic pressure?

2. 1. 5. 1. 3. 2. 1. 5  
What is the effect of the space environment on the internal pressure manifested in the active transport processes?
2. 1. 5. 1. 3. 2. 2  
What is the effect of the space environment on the acid-base balance manifested by extracellular fluids?
2. 1. 5. 1. 3. 2. 3  
What is the effect of the space environment on the acid-base balance manifested by extracellular electrolytes?
2. 1. 5. 1. 3. 2. 4. 1  
What is the effect of the space environment on the acid-base balance manifested by a change in the carbon-dioxide regulating system?
2. 1. 5. 1. 3. 2. 4. 2  
What is the effect of the space environment on the acid-base balance manifested by an alteration of the bio-electric properties of the protein?
2. 1. 5. 1. 3. 2. 5. 1  
What is the effect of the space environment on the heat exchange capacity manifested in a conservation process?
2. 1. 5. 1. 3. 2. 5. 2  
What is the effect of the space environment on the heat exchange capacity manifested in a respiratory exchange process?
2. 1. 5. 1. 3. 2. 5. 3  
What is the effect of the space environment on the heat exchange capacity manifested in a dermal exchange process?
2. 1. 5. 1. 4. 1. 1. 1  
What is the effect of the space environment on endocrine hormones?
2. 1. 5. 1. 4. 1. 2. 1  
What is the effect of the space environment on enzyme systems?
2. 1. 5. 1. 4. 1. 2. 2  
What is the effect of the space environment on exocrine lubricants?
2. 1. 5. 1. 4. 1. 2. 3  
What is the effect of the space environment on heat exchange capacity?

- 2. 1. 5. 1. 4. 2. 1  
What is the effect of the space environment on digestion of nutrients?
- 2. 1. 5. 1. 4. 2. 2  
What is the effect of the space environment on absorption of nutrients?
- 2. 1. 5. 1. 4. 3. 1  
What is the effect of the space environment on metabolism?
- 2. 1. 5. 1. 4. 3. 2  
What is the effect of the space environment on detoxification processes?
- 2. 1. 5. 1. 4. 3. 3  
What is the effect of the space environment on storage processes?
- 2. 1. 5. 1. 4. 4. 1  
What is the effect of the space environment on production of formed elements by the hematopoietic system?
- 2. 1. 5. 1. 4. 4. 2  
What is the effect of the space environment on hematopoietic storage capacity?
- 2. 1. 5. 1. 4. 5. 1  
What is the effect of the space environment on immune mechanism?
- 2. 1. 5. 1. 4. 5. 2  
What is the effect of the space environment on removal of foreign elements?
- 2. 1. 5. 1. 4. 5. 3  
What is the effect of the space environment on the removal of foreign elements?
- 2. 1. 5. 1. 4. 5. 3. 1  
What is the effect of the space environment on production of formed elements by the reticuloendothelial system?
- 2. 1. 5. 1. 4. 5. 3. 2  
What is the effect of the space environment on removal of formed elements by the reticuloendothelial system?
- 2. 1. 5. 1. 4. 6. 1  
What is the effect of the space environment on waste product removal process by renal organs?

- 2. 1. 5. 1. 4. 6. 2  
What is the effect of the space environment on acid-base balance by renal organs?
- 2. 1. 5. 1. 4. 6. 3  
What is the effect of the space environment on conservation of electrolytes by renal organs?
- 2. 1. 5. 1. 4. 6. 4  
What is the effect of the space environment on conservation of water by renal organs?
- 2. 1. 5. 1. 4. 7. 1  
What is the effect of the space environment on oogenesis?
- 2. 1. 5. 1. 4. 7. 2  
What is the effect of the space environment on spermatogenesis?
- 2. 1. 5. 1. 5. 1  
What is the effect of the space environment on senescence?
- 2. 1. 5. 1. 5. 2  
What is the effect of the space environment on life span?
- 2. 1. 5. 2. 1. 1  
What is the effect of the space environment on cutaneous sensation?
- 2. 1. 5. 2. 1. 2  
What is the effect of the space environment on audition?
- 2. 1. 5. 2. 1. 3  
What is the effect of the space environment on taste?
- 2. 1. 5. 2. 1. 4  
What is the effect of the space environment on olfactory sensation?
- 2. 1. 5. 2. 1. 5  
What is the effect of the space environment on vision?
- 2. 1. 5. 2. 1. 5. 1  
What is the effect of the space environment on brightness discrimination?
- 2. 1. 5. 2. 1. 5. 2  
What is the effect of the space environment on visual acuity?
- 2. 1. 5. 2. 1. 5. 3  
What is the effect of the space environment on visual spatial relationships?

2. 1. 5. 2. 1. 5. 4

What is the effect of the space environment on visual temporal relationships?

2. 1. 5. 2. 1. 5. 5

What is the effect of the space environment on the visual sensation of motion?

2. 1. 5. 2. 2. 2. 1

What is the effect of the space environment on the perception of color, manifested by an alteration in contrast?

2. 1. 5. 2. 2. 2. 2

What is the effect of the space environment on the perception of color, manifested by an alteration in field?

2. 1. 5. 2. 2. 2. 3

What is the effect of the space environment on the perception of color, manifested by an alteration in adaptation?

2. 1. 5. 2. 2. 3

What is the effect of the space environment on the perception of depth?

2. 1. 5. 2. 2. 4

What is the effect of the space environment on the perception of time?

2. 1. 5. 2. 2. 5

What is the effect of the space environment on the perception of sound?

2. 1. 5. 2. 3. 1

What is the role of conditioning on learning in the space environment?

2. 1. 5. 2. 3. 2

What is the role of discrimination on learning in the space environment?

2. 1. 5. 2. 3. 3

What is the role of maze design on learning in the space environment?

2. 1. 5. 2. 3. 4

What is the role of shifts and span of attention on learning in the space environment?

2. 1. 5. 2. 3. 5

What is the role of association on learning in the space environment?



- 2. 1. 5. 2. 3. 6  
What is the role of set effects on learning in the space environment?
- 2. 1. 5. 2. 3. 7  
What is the role of transfer effects on learning in the space environment?
- 2. 1. 5. 2. 3. 8  
What is the role of reasoning on learning in the space environment?
- 2. 1. 5. 2. 4. 1  
What is the effect of the space environment on memory interference?
- 2. 1. 5. 2. 4. 2  
What is the effect of the space environment on memory recall?
- 2. 1. 5. 2. 4. 3  
What is the effect of the space environment on memory recognition?
- 2. 1. 5. 2. 4. 4  
What is the effect of the space environment on memory retention?
- 2. 1. 5. 2. 5. 1  
What is the effect of the space environment on drives?
- 2. 1. 5. 2. 5. 2  
What is the effect of the space environment on primary and secondary incentives?
- 2. 1. 5. 2. 5. 3  
What is the effect of the space environment on nonorganic drives?
- 2. 1. 5. 2. 5. 4  
What is the effect of the space environment on learning motivation?
- 2. 1. 5. 2. 6. 1. 1  
What is the effect of the space environment on central nervous system?
- 2. 1. 5. 2. 6. 1. 2  
What is the effect of the space environment on sympathetic and parasympathetic nervous system?
- 2. 1. 5. 2. 6. 2. 1  
What is the effect on the space environment on circulation?

- 2. 1. 5. 2. 6. 2. 2  
What is the effect of the space environment on muscular tension?
- 2. 1. 5. 2. 6. 2. 3  
What is the effect of the space environment on respiration?
- 2. 1. 5. 3. 1. 1. 2. 1  
What is the effect of the space environment on aerosol pattern of penetration into respiratory tract?
- 2. 1. 5. 3. 1. 1. 2. 2  
What is the effect of the space environment on lodgement of microbes in respiratory tract?
- 2. 1. 5. 3. 1. 1. 2. 3. 1  
What is the effect of the space environment on disease transmission for different numbers of animals per chamber?
- 2. 1. 5. 3. 1. 1. 2. 3. 2  
What is the effect of the space environment on state of susceptibility or resistance?
- 2. 1. 5. 3. 1. 1. 2. 3. 3  
What is the effect of the space environment on disease transmission for different levels of confined space per animal?
- 2. 1. 5. 3. 1. 1. 2. 3. 4  
What is the effect of the space environment on number of microbes released by infected animal?
- 2. 1. 5. 3. 1. 1. 2. 3. 5  
What is the effect of the space environment on type of aerosol produced?
- 2. 1. 5. 3. 1. 1. 2. 4  
What is the effect of the space environment on course of infection?
- 2. 1. 5. 3. 3. 1. 1  
What is the effect of the space environment on course of response to vaccines?
- 2. 1. 5. 3. 3. 1. 2  
What is the effect of the space environment on course of response to other antigens?
- 2. 1. 5. 3. 3. 7. 1  
What is the effect of the space environment on degradation of immune mechanisms, namely microbial shock on return to Earth?

**EARTH ORBITAL EXPERIMENT PROGRAM  
AND REQUIREMENTS STUDY**

**SPACE BIOLOGY**

**RESEARCH CLUSTER-2-VB-3  
ADVANCED INVESTIGATIONS OF BIOLOGICAL PROCESSES,  
USING PRIMATES AND SMALL VERTEBRATES**

*C-2-28*

Critical Issues Addressed by Research Cluster  
2-VB-3

ADVANCED INVESTIGATIONS OF BIOLOGICAL PROCESSES,  
USING PRIMATES AND SMALL VERTEBRATES

- 2.1.1.1.1.1.4  
What is the effect of the space environment on the biosynthesis of glycogen?
- 2.1.1.1.1.1.7  
What is the effect of the space environment on the biosynthesis of other polysaccharides?
- 2.1.1.1.1.2.1  
What is the effect of the space environment on the biosynthesis of creatine phosphate?
- 2.1.1.1.1.3.1  
What is the effect of the space environment on the biosynthesis of acetyl coenzyme-A?
- 2.1.1.1.2.2.1.1  
What is the effect of the space environment on the anabolism of calcium?
- 2.1.1.1.2.2.1.2  
What is the effect of the space environment on the anabolism of phosphorus?
- 2.1.1.1.2.2.1.3  
What is the effect of the space environment on the anabolism of other skeletal minerals?
- 2.1.1.1.2.2.2.1  
What is the effect of the space environment on the anabolism of sodium?
- 2.1.1.1.2.2.2.2  
What is the effect of the space environment on the anabolism of potassium?
- 2.1.1.1.2.2.2.3  
What is the effect of the space environment on the anabolism of chloride?
- 2.1.1.1.2.2.2.4  
What is the effect of the space environment on the anabolism of other nonskeletal minerals?

- 2.1.1.1.2.3.1  
What is the effect of the space environment on the biosynthesis of muscle protein?
- 2.1.1.1.2.3.2  
What is the effect of the space environment on the biosynthesis of collagen?
- 2.1.1.1.2.3.3  
What is the effect of the space environment on the biosynthesis of other proteins?
- 2.1.1.1.3.2.1.2  
What is the effect of the space environment on the biosynthesis of DNA?
- 2.1.1.1.3.2.1.3.1  
What is the effect of the space environment on the biosynthesis of Messenger RNA?
- 2.1.1.1.3.2.1.3.2  
What is the effect of the space environment on the biosynthesis of Transfer RNA?
- 2.1.1.1.3.2.1.3.3  
What is the effect of the space environment on the biosynthesis of ribosomal RNA?
- 2.1.1.1.3.2.1.3.4  
What is the effect of the space environment on the biosynthesis of other RNA's?
- 2.1.1.1.3.2.2  
What is the effect of the space environment on the biosynthesis of histones?
- 2.1.1.2.1.2.1  
What is the effect of the space environment on the metabolic control functions of thyroid hormones?
- 2.1.1.2.1.2.2  
What is the effect of the space environment on the metabolic control functions of parathyroid hormones?
- 2.1.1.2.1.2.3  
What is the effect of the space environment on the metabolic control functions of gonadal hormones?
- 2.1.1.2.1.2.4  
What is the effect of the space environment on the metabolic control functions of adrenal cortical hormones?

- 2.1.1.2.1.2.5  
What is the effect of the space environment on the metabolic control functions of adrenal medulla hormones?
- 2.1.1.2.1.2.6  
What is the effect of the space environment on the metabolic control functions of pancreatic hormones?
- 2.1.1.2.1.2.7  
What is the effect of the space environment on the metabolic control functions of adenohipophyseal hormones?
- 2.1.1.2.1.2.8  
What is the effect of the space environment on the metabolic control functions of neurohipophyseal hormones?
- 2.1.1.2.1.2.9  
What is the effect of the space environment on the metabolic control functions of other hormones?
- 2.1.1.2.2.3  
Will inborn errors in metabolism occur due to the space environment?
- 2.1.1.3.1.1.1  
What is the effect of the space environment on the breakdown of ATP?
- 2.1.1.3.1.1.2  
What is the effect of the space environment on the breakdown of UTP?
- 2.1.1.3.1.1.3  
What is the effect of the space environment on the breakdown of ITP?
- 2.1.1.3.1.1.4  
What is the effect of the space environment on the breakdown of GTP?
- 2.1.1.3.1.3.1.1  
What is the effect of the space environment on the breakdown of adenine?
- 2.1.1.3.1.3.1.2  
What is the effect of the space environment on the breakdown of hypoxanthine?
- 2.1.1.3.1.3.1.3  
What is the effect of the space environment on the breakdown of xanthine?

- 2.1.1.3.1.3.1.4  
What is the effect of the space environment on the breakdown of **guanine** ?
- 2.1.1.3.1.3.2.1  
What is the effect of the space environment on the breakdown of uracil?
- 2.1.1.3.1.3.2.2  
What is the effect of the space environment on the breakdown of cytosine?
- 2.1.1.3.1.3.2.3  
What is the effect of the space environment on the breakdown of thymine?
- 2.1.1.3.1.4.1  
What is the effect of the space environment on the breakdown of ribose?
- 2.1.1.3.1.4.2  
What is the effect of the space environment on the breakdown of deoxyribose?
- 2.1.1.3.2.1  
What is the effect of the space environment on glycogenic processes?
- 2.1.1.3.2.2  
What is the effect of the space environment on amino acid pools?
- 2.1.1.3.2.3  
What is the effect of the space environment on ketogenic processes?
- 2.1.1.3.3.1.1  
What is the effect of the space environment on beta-oxidation of fatty acids?
- 2.1.1.3.3.1.2  
What is the effect of the space environment on omega-oxidation of fatty acids?
- 2.1.1.3.3.2  
What is the effect of the space environment on the catabolism of triglycerides?
- 2.1.1.3.4.1.1  
What is the effect of the space environment on carbohydrate catabolism through the pentose phosphate shunt?

2.1.1.3.4.1.2

What is the effect of the space environment on carbohydrate catabolism through the TCA cycle?

2.1.1.3.4.2.1

What is the effect of the space environment on carbohydrate catabolism through the glycolytic mechanisms?

2.1.1.3.4.2.2

What is the effect of the space environment on carbohydrate catabolism through the nonglycolytic mechanisms?

2.1.2.1.1.1.1

What is the effect of the space environment on the reaction mediated by the enzyme, pyruvic oxidase?

2.1.2.1.1.1.2

What is the effect of the space environment on the reaction mediated by the isocitric enzyme?

2.1.2.1.1.1.3

What is the effect of the space environment on the reaction mediated by the enzyme, alpha ketoglutarate oxidase?

2.1.2.1.1.1.4

What is the effect of the space environment on the reaction mediated by the enzyme, succinyl thiokinase?

2.1.2.1.1.1.5

What is the effect of the space environment on the reaction mediated by the enzyme, succinic dehydrogenase?

2.1.2.1.1.1.6

What is the effect of the space environment on the reaction mediated by the enzyme, malic dehydrogenase?

2.1.2.1.1.2.1

What is the effect of the space environment on the formation of ATP at the NAD/FAD crossover point?

2.1.2.1.1.2.2

What is the effect of the space environment on the formation of ATP at the FAD/cytochrome C crossover point?

2.1.2.1.1.2.3

What is the effect of the space environment on the formation of ATP at the cytochrome C/cytochrome oxidase crossover point?



2.1.2.1.1.3.1

What is the effect of the space environment on the reaction mediated by the enzyme, glucose-6-phosphate dehydrogenase?

2.1.2.1.1.3.2

What is the effect of the space environment on the reaction mediated by the enzyme, 6-phospho gluconic acid dehydrogenase?

2.1.2.1.1.4.1

What is the effect of the space environment on the reaction mediated by the enzyme, acyl dehydrogenase?

2.1.2.1.1.4.2

What is the effect of the space environment on the reaction mediated by the enzyme, hydroxyacyl dehydrogenase?

2.1.2.1.1.5.2

What is the effect of the space environment on the reaction mediated by glutamic acid dehydrogenase?

2.1.2.1.1.6.1

What is the effect of the space environment on the reactions mediated by the transaminases?

2.1.2.1.2.1.1

What is the effect of the space environment on the glycolitic reaction mediated by the enzyme, phosphoglyceraldehyde dehydrogenase?

2.1.2.1.2.1.2

What is the effect of the space environment on the glycolitic reaction mediated by the enzyme, phosphoglyceryl kinase?

2.1.2.1.2.1.3

What is the effect of the space environment on the glycolitic reaction mediated by the enzyme, pyruvic oxidase?

2.1.3.2.1.1

What is the effect of the space environment on circadian rhythms, as manifested by organism activity?

2.1.3.2.1.2

What is the effect of the space environment on circadian rhythms, as manifested by feeding?

2.1.3.2.5.2

What is the effect of the space environment on annual rhythms, such as hibernation (depressed metabolism/hypothermia)?

2.1.3.2.7.2.1

What is the effect of the space environment on metabolic and/or energetic alterations of rhythm resulting from nuclear control?

2.1.3.2.7.2.2

What is the effect of the space environment on metabolic and/or energetic alterations of rhythm resulting from oscillations in membrane properties?

2.1.4.1.1.1.1

What is the effect of the space environment on fertilization?

2.1.4.1.1.1.2

What is the effect of the space environment on cleavage?

2.1.4.1.1.1.3

What is the effect of the space environment on differentiation?

2.1.4.2.1.3.1

What effect does the space environment have on the frequency of nonlethal mutations manifested as structural abnormalities?

2.1.4.2.1.3.2

What is the effect of the space environment on biochemical abnormalities?

2.1.4.2.1.3.3

What is the effect of the space environment on chromosomal abnormalities?

2.1.5.1.1.1.1.1

What is the effect of the space environment on exteroceptive nerves?

2.1.5.1.1.1.1.2

What is the effect of the space environment on interoceptive nerves?

2.1.5.2.2.2.2.3

What is the effect of the space environment on proprioceptive nerves?

2.1.5.1.1.1.2.1

What is the effect of the space environment on neuromotor nerves?

2.1.5.1.1.1.2.2

What is the effect of the space environment on sympathetic nervous system?

2.1.5.1.1.1.2.3

What is the effect of the space environment on parasympathetic nervous system?

2.1.5.1.1.1.2.4

What is the effect of the space environment on secretory nerves?

2.1.5.1.1.2.1.1

What is the effect of the space environment on reflex mechanisms?

2.1.5.1.1.2.1.2

What is the effect of the space environment on conduction pathways?

2.1.5.1.1.2.1.3

What is the effect of the space environment on facilitation and inhibition mechanisms?

2.1.5.1.1.2.2.1

What is the effect of the space environment on motor control centers?

2.1.5.1.1.2.2.2

What is the effect of the space environment on visceral control centers?

2.1.5.1.1.2.2.3

What is the effect of the space environment on centers associated with learning?

2.1.5.1.1.2.2.4

What is the effect of the space environment on centers associated with memory?

2.1.5.1.1.2.2.5

What is the effect of the space environment on centers associated with emotion?

2.1.5.1.2.1.1.1.1

What is the effect of the space environment on locomotion muscles?

2.1.5.1.2.1.1.1.2

What is the effect of the space environment on support muscles?

2.1.5.1.2.1.1.1.3

What is the effect of the space environment on muscles associated with the respiratory system?

- 2.1.5.1.2.1.1.1.4  
What is the effect of the space environment on muscles associated with organs?
- 2.1.5.1.2.1.1.2  
What is the effect of the space environment on voluntary nonstriated muscles?
- 2.1.5.1.2.1.2.1.1  
What is the effect of the space environment on cardiac muscle?
- 2.1.5.1.2.1.2.1.2  
What is the effect of the space environment on muscles associated with the respiratory system?
- 2.1.5.1.2.1.2.1.3  
What is the effect of the space environment on muscles associated with temperature regulation?
- 2.1.5.1.2.2.1.1  
What is the effect of the space environment on musculo-skeletal attachments?
- 2.1.5.1.2.2.1.2  
What is the effect of the space environment on skeletal articulation?
- 2.1.5.1.3.1.1  
What is the effect of the space environment on the transport of organic nutrients?
- 2.1.5.2.3.1.2  
What is the effect of the space environment on the transport of inorganic nutrients?
- 2.1.5.1.3.1.3.1  
What is the effect of the space environment on the transport of respiratory gases, as manifested in the respiratory pigments?
- 2.1.5.1.3.1.3.2  
What is the effect of the space environment on the transport of respiratory gases, as manifested in the gas solubility?
- 2.1.5.1.3.1.4  
What is the effect of the space environment on the transport of organic waste products?
- 2.1.5.1.3.1.5  
What is the effect of the space environment on the transport of inorganic waste products?

2.1.5.1.3.1.6

What is the effect of the space environment on the transport of hormones?

2.1.5.1.3.2.1.1

What is the effect of the space environment on internal pressure as manifested in the regulatory mechanisms?

2.1.5.1.3.2.1.2

What is the effect of the space environment on internal pressure as manifested in the cardiodynamics?

2.1.5.1.3.2.1.3

What is the effect of the space environment on internal pressure as manifested in the hemodynamics?

2.1.5.1.3.2.1.4

What is the effect of the space environment on internal pressure as manifested in the osmotic pressure?

2.1.5.1.3.2.1.5

What is the effect of the space environment on internal pressure as manifested in the active transport processes?

2.1.5.1.3.2.2

What is the effect of the space environment on extracellular fluids?

2.1.5.1.3.2.3

What is the effect of the space environment on extracellular electrolytes?

2.1.5.1.3.2.4.1

What is the effect of the space environment on acid-base balance, as manifested by a change in the carbon dioxide regulating system?

2.1.5.1.3.2.4.2

What is the effect of the space environment on acid-base balance, as manifested by an alteration of the bioelectric properties of the protein?

2.1.5.1.3.2.5.1

What is the effect of the space environment on heat exchange capacity, as manifested in a conservation process?

2.1.5.1.3.2.5.2

What is the effect of the space environment on heat exchange capacity, as manifested in a respiratory exchange process?

2.1.5.1.3.2.5.3

What is the effect of the space environment on heat exchange capacity, as manifested in a dermal exchange process?

2.1.5.1.4.1.1.1

What is the effect of the space environment on endocrine hormones?

2.1.5.1.4.1.2.1

What is the effect of the space environment on enzyme systems?

2.1.5.1.4.1.2.2

What is the effect of the space environment on exocrine lubricants?

2.1.5.1.4.1.2.3

What is the effect of the space environment on heat exchange capacity?

2.1.5.1.4.2.1

What is the effect of the space environment on digestion of nutrients?

2.1.5.1.4.2.2

What is the effect of the space environment on absorption of nutrients?

2.1.5.1.4.3.1

What is the effect of the space environment on metabolism in hepatic organs?

2.1.5.1.4.3.2

What is the effect of the space environment on detoxification processes in hepatic organs?

2.1.5.1.4.3.3

What is the effect of the space environment on storage processes in hepatic organs?

2.1.5.1.4.4.1

What is the effect of the space environment on production of formed elements in hemopoetic organs?

2.1.5.1.4.4.2

What is the effect of the space environment on storage capacity in hemopoetic organs?

2.1.5.1.4.5.1

What is the effect of the space environment on immune mechanisms?

2.1.5.1.4.5.2

What is the effect of the space environment on removal of foreign elements by the reticuloendothelial system?

2.1.5.1.4.5.3.1

What is the effect of the space environment on production of formed elements by the reticuloendothelial system?

2.1.5.1.4.5.3.2

What is the effect of the space environment on removal of formed elements by the reticuloendothelial system?

2.1.5.1.4.6.1

What is the effect of the space environment on the waste product removal process by renal organs?

2.1.5.1.4.6.2

What is the effect of the space environment on the acid-base balance by renal organs?

2.1.5.1.4.6.3

What is the effect of the space environment on the conservation of electrolytes by renal organs?

2.1.5.1.4.6.4

What is the effect of the space environment on the conservation of water?

2.1.5.1.4.7.1

What is the effect of the space environment on oogenesis?

2.1.5.1.4.7.2

What is the effect of the space environment on spermatogenesis?

2.1.5.1.5.1

What is the effect of the space environment on senescence?

2.1.5.1.5.2

What is the effect of the space environment on life span?

2.1.5.2.1.1

What is the effect of the space environment on cutaneous sensation?

2.1.5.2.1.2

What is the effect of the space environment on audition?

2.1.5.2.1.3

What is the effect of the space environment on taste?

2.1.5.2.1.4

What is the effect of the space environment on olfactory sensation?

2.1.5.2.1.5.1

What is the effect of the space environment on vision as manifested by brightness?

2.1.5.2.1.5.2

What is the effect of the space environment on vision as manifested by acuity?

2.1.5.2.1.5.3

What is the effect of the space environment on vision as manifested by spatial relationships?

2.1.5.2.1.5.4

What is the effect of the space environment on vision as manifested by temporal relationships?

2.1.5.2.1.5.5

What is the effect of the space environment on vision as manifested by motion?

2.1.5.2.2.1

What is the effect of the space environment on color perception, as manifested by an alteration in perception of visual form?

2.1.5.2.2.2.1

What is the effect of the space environment on color perception, as manifested by an alteration in contrast?

2.1.5.2.2.2.2

What is the effect of the space environment on color perception, as manifested by an alteration in field?

2.1.5.2.2.2.3

What is the effect of the space environment on color perception, as manifested by an alteration in adaptation?

2.1.5.2.2.3

What is the effect of the space environment on perception in depth?

2.1.5.2.2.4

What is the effect of the space environment on perception of time?



- 2.1.5.2.2.5  
What is the effect of the space environment on the perception of sound?
- 2.1.5.2.3.1  
What is the role of conditioning on learning in the space environment?
- 2.1.5.2.3.2  
What is the role of discrimination on learning in the space environment?
- 2.1.5.2.3.3  
What is the role of maze design on learning in the space environment?
- 2.1.5.2.3.4  
What is the role of shifts and span of attention on learning in the space environment?
- 2.1.5.2.3.5  
What is the role of association on learning in the space environment?
- 2.1.5.2.3.6  
What is the role of set effects on learning in the space environment?
- 2.1.5.2.3.7  
What is the role of transfer effects on learning in the space environment?
- 2.1.5.2.3.8  
What is the role of reasoning on learning in the space environment?
- 2.1.5.2.4.1  
What is the effect of the space environment on interference?
- 2.1.5.2.4.2  
What is the effect of the space environment on recall?
- 2.1.5.2.4.3  
What is the effect of the space environment on recognition?
- 2.1.5.2.4.4  
What is the effect of the space environment on retention?
- 2.1.5.2.5.1  
What is the effect of the space environment on drives?

2.1.5.2.5.2

What is the effect of the space environment on primary and secondary incentives?

2.1.5.2.5.3

What is the effect of the space environment on nonorganic drives?

2.1.5.2.5.4

What is the effect of the space environment on learning?

2.1.5.2.6.1.1

What is the effect of the space environment on the central nervous system?

2.1.5.2.6.1.2

What is the effect of the space environment on the sympathetic and parasympathetic nervous system?

2.1.5.2.6.2.1

What is the effect of the space environment on circulation?

2.1.5.2.6.2.2

What is the effect of the space environment on muscular tension?

2.1.5.2.6.2.3

What is the effect of the space environment on respiration?

2.1.5.3.3.2

What is the effect of the space environment on secretion of immune globulin A?

2.1.5.3.3.3

What is the effect of the space environment on the thymus function?

2.1.5.3.3.4

What is the effect of the space environment on response and transformation of lymphocytes?

2.1.5.3.3.5

What is the effect of the space environment on synthesis of immune globulin?

2.1.5.3.3.6

What is the effect of the space environment on macrophage antigen processing?

2.1.5.3.3.7.2

What is the effect of the space environment on degradation of immune mechanisms, namely long-term inflight effect on susceptibility to infection?

2.1.5.3.3.8.1

What is the effect of the space environment on local host defenses, namely mucociliary function?

2.1.5.3.3.8.2

What is the effect of the space environment on local host defenses, namely phagocytic clearance?

2.1.5.3.3.8.3

What is the effect of the space environment on local host defenses, namely lysozyme concentration in secretions and blood?

2.1.5.3.3.8.4

What is the effect of the space environment on local host defenses, namely peristalsis?

2.1.5.3.4.1

What is the effect of the space environment on factors that alter host defenses?

2.1.5.3.4.2

What is the effect of the space environment on factors that activate latent infections?

TABLE 1. LEGEND OF CODES USED IN CREW ACTIVITY MATRICES

Table 1 is an explanation of the codes used in the following matrices. The matrices summarize the inflight crew tasks required to conduct and support the research identified in the synopsis.

#### TYPE OF ACTIVITY

- |   |   |
|---|---|
| 0 - Not covered below                   | 5 - Conduct of experiment   |
| 1 - Experimental subject                | 6 - Evaluate intermediate results   |
| 2 - Spacecraft operations               | 7 - Direct observation of phenomena                                       |
| 3 - Preexperiment equipment preparation | 8 - Data handling   |
| 4 - Maintenance of equipment            | 9 - Communications; initiate and receive transmissions (telemetry, voice) |

#### CREW SKILL

- |                               |                      |
|-------------------------------|----------------------|
| 0 - No special skill required | 12 - Meteorology     |
| 1 - Medicine                  | 13 - Geography       |
| 2 - Biology                   | 14 - Cartography     |
| 3 - Physiology                | 15 - Hydrology       |
| 4 - Psychology                | 16 - Navigation      |
| 5 - Engineering               | 17 - Communications  |
| 6 - Astronomy                 | 18 - Radiology       |
| 7 - Physics                   | 19 - Instrumentation |
| 8 - Oceanography              | 20 - Photography     |
| 9 - Forestry                  | 21 - Astronaut       |
| 10 - Agriculture              | 22 - Other           |
| 11 - Geology                  |                      |

Each code includes the first one or two digits describing the discipline and a second code letter describing level of skill: A for highest skill level (requires professional training with degree or advanced degree in discipline such as M. D.); B for semiprofessional, the traditional technician level requiring several years of training; C for technician level which requires some special training.

C-2-43-a

CREW ACTIVITY MATRIX (Page 1 of 3)

RESEARCH CLUSTER NO.	TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE	CREW SKILL	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START	DURATION	TASK CONCURRENCY
2-VB-1	(a) Small Mammals in Space											
(p. 1 of 3)	1. Open compartments and remove young	mouse modules	3		X	3c	once per 90 days	15 min	1	'74	missing length	
	2. Examine for developmental abnormalities	hand lens	5		X	3c	"	15 min	1	'74	"	
	3. Separate by sex and place in compartments	mouse modules	5		X	3c	"	30 min	1	'74	"	
	4. Recompartment mature mice in pairs	mouse modules	5		X	3c	"	30 min	1	'74	"	
	5. Calibrate mass spectrometer	mass spectrometer	4		X	3c	"	30 min	1	'74	"	
	6. Resupply modules	N <sub>2</sub> , O <sub>2</sub> and food	4		X	3c	"	30 min	1	'74	"	
	7. Replace waste and air stream filters	filters	4		X	3c	"	15 min	1	'74	"	
	8. Activate LS/EC system in new compartments	modules	4		X	3c	"	5 min	1	'74	"	
	(b) Restrained Primate Experiment											
	1. Monitoring of primate well-being	primate modules	4		X	3c	daily	10 min	1	'74	180 days	
	2. Prepare primate for return	"	3		X	3c	once only	2 hrs	1	'74	—	
	(c) Weight Change in Rats											
	1. Set up specimen mass measurement device (SMMD)	SMMD	3		X	3c	daily	5 min	1	'76	90 days	
	2. Remove animals from cages	rat modules	5		X	3c	daily	10 min	1	'76	"	
	3. Weigh animals on SMMD	SMMD	5		X	3c	daily	85 min	1	'76	"	
	4. Record data	data sheets	8		X	3c	daily	5 min	1	'76	"	
	5. Return animals to cages	rat modules	3		X	3c	daily	10 min	1	'76	"	
	(d) Alterations in Rats' Respiratory Quotient											
	1. Observe spectrometer data display for O <sub>2</sub> and CO <sub>2</sub> measurements	mass spectrometer	5		X	0	daily	3 min	1	'76	"	
	2. Record data	data sheets	3		X	0	daily	2 min	1	'76	"	
	(e) Gravity-level Preference in Rats											
	1. Place rat cage on biocentrifuge	biocentrifuge	3		X	3c	twice/day	3 min	1	'78	30 days	
	2. Observe position of rats along centrifuge arm	"	5		X	3c	"	10 min	1	'78	"	
	3. Record data	data sheets	8		X	3c	"	2 min	1	'78	"	
	4. Change angular velocity of centrifuge	biocentrifuge	3		X	3c	every 2nd day	5 min	1	'78	"	
	5. Repeat "1," "2," and "3"	---	3, 5, & 8		X	3c	twice/day	15 min	1	'78	"	

RESEARCH CLUSTER NO.	TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE	CREW SKILL	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START	DURATION	TASK CONCURRENCY
2-VB-1 (p. 2 of 3)												
	6. Return cage to holding facility	rat module	3		X	3c	twice/day		1	'78	30 days	
(f)	Activity Cycles in Rats											
	1. Visual checks of activity periods	rat module	5		X	3c	every 2nd day	15 min	1	'76	6 mos	
	2. Record data	data sheets	8		X	3c	"	2 min	1	'76	"	
(g)	Fertilization and Embryogenesis in Rats											
	1. Make visual counts of pregnancies per cage	rat module	5		X	3c	daily	1 min	1	Post '80	30 days	
	2. Observe progress of pregnancies	"	5		X	3c	"	1 min	1	"	"	
	3. Set up surgical and preservation equipment	animal surgery	3		X	3b	"	10 min	1	"	"	
	4. Select and remove chosen females from cages	rat module	5		X	3b	"	1 min	1	"	"	
	5. Sacrifice females and remove embryos	animal surgery	5		X	3b	"	15 min	1	"	"	
	6. Weigh and preserve embryos	SMD	5		X	3b	"	15 min	1	"	"	
	7. Record data	data sheets	8		X	3b	"	10 min	1	"	"	
	8. Dispose of sacrificed adult rats	incinerator	3		X	3c	"	10 min	1	"	"	
(h)	Wound healing											
	1. Set up surgical equipment	animal surgery	3		X	3b	once only	30 min	1	"	—	
	2. Remove rats from cages	rat module	5		X	3c	"	5 min	1	"	—	
	3. Anesthetize and produce specified wounds	anesthetizer	5		X	3b	"	1 hr	1	"	—	
	4. Dress wounds and return rats to cages	rat module	5		X	3b	"	1 hr	1	"	—	
	5. Observe state of wound	"	5		X	3b	every 2 days	30 min	1	"	1 mo.	
	6. Record data	data sheets	8		X	3b	"	10 min	1	"	"	
(i)	Sensory Response and Motor Control											
	1. Check operation of automatic equipment	---	4		X	3c	daily	5 min	1	'78	180 days	
(j)	Homeostatic Processes											
	1. Check health of animals, state of catheters, and operation of implanted sensors	---	4		X	3c	weekly	30 min	1	Post '80	"	
(k)	Acid-Base Balance and Stress											
	1. Set up urine collection devices and specimen containers	urine collection system	3		X	3c	weekly	15 min	1	'78	"	

RESEARCH CLUSTER NO.	TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE	CREW SKILL	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START	DURATION	TASK CONCURRENCY
2-VB-1 (p. 3 of 3)												
	2. Set up pH meter	pH meter	3		X	3c	weekly	10 min	1	'78	180 days	
	3. Remove animals from cage	rat module	5		X	3c	"	10 min	1	'78	"	
	4. Obtain urine and arterial blood samples	urine and blood sampling system	5		X	3b	"	60 min	1	'78	"	
	5. Measure pH of blood and urine	pH meter	5		X	3b	"	60 min	1	'78	"	
	6. Store urine samples in freezer	freezer	3		X	3c	"	30 min	1	'78	"	
	7. Discard blood samples	waste management system	3		X	3c	"	10 min	1	'78	"	
	8. Record blood and urine pH and urine volume	data sheets	8		X	3c	"	10 min	1	'78	"	
	(1) Infectious Processes and Organ Alterations											
	1. Expose selected rats to infectious agents	exposure chamber	5			3b	once only	3 hrs	1	Post '80	--	
	2. Remove rats from cages (infected animals and controls)	rat module	5		X	3b	weekly	5 min	1	"	6 mos	
	3. Sacrifice animals and remove organs	animal surgery	5		X	3b	"	20 min	1	"	"	
	4. Examine for evidence of infection and gross alterations	"	5		X	3b	"	20 min	1	"	"	
	5. Set up and calibrate SMD	SMD	3		X	3c	"	5 min	1	"	"	
	6. Weigh organs	SMD	5		X	3c	"	40 min	1	"	"	
	7. Record data	data sheets	8		X	3c	"	10 min	1	"	"	
	8. Preserve organs	freezer	3		X	3c	"	10 min	1	"	"	
	9. Sterilize and dispose of remains	autoclave	3			3c		85 min	1	"	"	
	(m) Life Span											
	1. Make visual count of dead animals per cage	rat module	5		X	0	daily	2 min	1	'76	180 days	
	2. Remove and dispose of dead animals	incinerator	3		X	0	as necessary	15 min	1	"	"	
	(n) Electrophysiological Measurements											
	1. Check animals well-being and status of implanted electrodes	---	4		X	3c	weekly	30 min	1	Post '80	"	

CREW ACTIVITY MATRIX (Page 1 of 3)

RESEARCH CLUSTER NO.	TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE	CREW SKILL	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START	DURATION	TASK CONCURRENCY
2-VB-2	(a) Measurement of nerve action potentials											
(p. 1 of 3)	1. Anesthetize animal	anesthetizer	3		X	2b	weekly	15 min	1	'78	6 wks	
	2. Dissect and remove sciatic nerve	animal surgery	3		X	2b	"	15 min	1	"	"	
	Place nerve in stimulator chamber and prepare for stimulation	nerve chamber	3		X	2b	"	5 min	1	"	"	
	3. Set up oscilloscope, camera, and stimulator -- connect leads	oscilloscope, stimulator, camera	5		X	2c	"	15 min	1	"	"	
	5. Determine stimulation threshold	"	5		X	2b	"	10 min	1	"	"	
	6. Obtain and photograph graded response with increasing stimuli	"	5		X	2b	"	10 min	1	"	"	
	7. Observe effects of catelectrotonus and anelectrotonus	direct current stimulator	5		X	2b	"	15 min	1	"	"	
	8. Remove and store film	camera and film storage unit	8		X	2c	"	5 min	1	"	"	
	9. Disassemble apparatus and dispose of specimen	incinerator	3		X	2c	"	15 min	1	"	"	
	(b) Measurement of Muscle Strength of Contraction											
	1. Anesthetize animal	anesthetizer	3		X	2b	"	15 min	1	"	"	
	2. Dissect and prepare gastrocnemius muscle for stimulation and recording	animal surgery	3		X	2b	"	20 min	1	"	"	
	3. Set up stimulator, strain gauge and recorder	stimulator, strain gauge, kymograph	3		X	2c	"	15 min	1	"	"	
	4. Determine threshold stimulus for contraction	"	5		X	2b	"	10 min	1	"	"	
	5. Obtain graded response with increasing stimuli	"	5		X	2b	"	10 min	1	"	"	
	6. Remove, label, and store kymograph records	kymograph records	8		X	2c	"	15 min	1	"	"	
	7. Disassemble apparatus and dispose of specimen	incinerator	3		X	2c	"	15 min	1	"	"	
	(c) Calorimetric Measurement											
	1. Set up calorimetry chamber	calorimeter	3		X	2c	twice weekly	10 min	1	'76	"	
	2. Calibrate mass spectrometer, hygrometer & thermometer	thermometer	3		X	2c	"	30 min	1	"	"	
	3. Set up specimen mass measurement device	SMMD	3		X	2c	"	5 min	1	"	"	
	4. Remove animals from cage and weigh	animal cages, SMMD	5		X	2b	"	40 min	1	"	"	
	5. Place animals in calorimeter and actuate	calorimeter	5		X	2b	"	5 min	1	"	"	
	6. Remove record from recorder and store	recorder and storage unit	8		X	2c	"	5 min	1	"	"	
	7. Remove animal from calorimeter, weight & return to cage	SMMD	3		X	2b	"	45 min	1	"	"	
	8. Disassemble apparatus	---	3		X	2c	"	15 min	1	"	"	



RESEARCH CLUSTER NO.	TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY	REMARKS	EXCLUSIVE	CREW SKILL	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START	DURATION	TASK CONCURRENCY
2-VB-2 (p. 2 of 3)												
(d)	Strength Testing (Bone)											
	1. Anesthetize animal	anesthetizer	3		X	2b	weekly	15 min	1	'78	6 wks	
	2. Dissect and remove bone sample	animal surgery	3		X	2b	"	15 min	1	"	"	
	3. Set up specimen mass measurement device	SPMD	3		X	2c	"	5 min	1	"	"	
	4. Weigh and measure bone sample	SPMD and micrometer	5		X	2c	"	25 min	1	"	"	
	5. Set up and calibrate force applicator	force applicator	3		X	2c	"	15 min	1	"	"	
	6. Position bone sample and actuate	"	5		X	2b	"	10 min	1	"	"	
	7. Record force at which sample fractures	"	5		X	2c	"	5 min	1	"	"	
	8. Remove sample and dispose of animal	incinerator	3		X	2c	"	15 min	1	"	"	
	9. Disassemble apparatus		3		X	2c	"	15 min	1	"	"	
(e)	Titer Dilution											
	1. Obtain blood samples	syringes and needles	3	6 crewmen will serve as subjects 5 min/man	X	2b	"	30 min	1	"	"	
	2. Centrifuge	laboratory centrifuge	3			2c	"	15 min	1	"	"	
	3. Remove serum and place in dilution tubes	pipettes & tubes	3		X	2c	"	10 min	1	"	"	
	4. Add reagents and incubate	incubator	5		X	2b	"	24 hrs	1	"	"	
	5. Observe for antigen-antibody reaction and end-point	optical densitometer	5		X	2b	"	30 min	1	"	"	
	6. Record results	data sheets	8		X	2b	"	10 min	1	"	"	
	7. Dispose of sample and other waste	--	3		X	2c	"	10 min	1	"	"	
(f)	Spermatozoogenesis											
	1. Obtain semen samples	container	3		X	2b	"	1 hr	1	"	12 wks	
	2. Measure total volume	graduated pipette	5		X	2b	"	20 min	1	"	"	
	3. Measure sample viscosity	viscometer	5		X	2b	"	30 min	1	"	"	
	4. Dilute sample	---	3		X	2b	"	15 min	1	"	"	
	5. Place in cell counting chamber	cell counter	5		X	2b	"	10 min	1	"	"	
	6. Charge chamber and count cells	"	5		X	2b	"	2 hrs	1	"	"	
	7. Record results	data sheets	8		X	2b	"	10 min	1	"	"	

RESEARCH CLUSTER NO.	TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE	CREW SKILL	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START	DURATION	TASK CONCURRENCY
2-VB-2 (p. 3 of 3)												
	8. Dispose of sample and restore equipment	---	3		X	2c	weekly	15 min	1	'78	12 wks	
(g)	Psychomotor Testing of Primates											
	1. Set-up and program testing device	psychomotor tester	3	more than one type of psychomotor test will be involved	X	2b	3 times per week	30 min	1	'76	6 wks	
	2. Remove primate from cage	conditioned primate	3		X	2b	"	10 min	1	"	"	
	3. Place primate in testing device and initiate test	psychomotor tester	5		X	2b	"	15 min	1	"	"	
	4. Monitor test	observation window	5			2b	"	1 hr	1	"	"	
	5. Remove record and store	recorder	8		X	2c	"	10 min	1	"	"	
	6. Return primate to cage	primate module	3		X	2b	"	10 min	1	"	"	
	7. Check calibration and store device	psychomotor tester	3		X	2c	"	15 min	1	"	"	
(h)	Investigation of Transport Processes											
	1. Supply animals with isotopically tagged nutrients	tagged food	3 & 5			2c	once per 2 weeks	15 min	1	Post '80	26 wks	
	2. Remove collected urine	urine collector	3		X	2c	daily	15 min	1	"	"	
	3. Measure urine volume and extract aliquots	graduated pipette	5		X	2c	"	30 min	1	"	"	
	4. Remove collected feces	waste management system	3		X	2c	"	15 min	1	"	"	
	5. Set up and calibrate specimen mass measurement device	SMMD	3		X	2c	"	5 min	1	"	"	
	6. Weigh feces	SMMD	5		X	2c	"	85 min	1	"	"	
	7. Dry feces and reweigh	drying oven and SMMD	5			2c	"	2 hrs	1	"	"	
	8. Obtain blood samples	syringes and needles	3		X	2b	weekly	20 min	1	"	"	
	9. Centrifuge and remove plasma	centrifuge	3			2c	"	20 min	1	"	"	
	10. Make required dilutions and analyze all samples for radioactivity	radiation detector	5			2b	"	2 hrs	1	"	"	
	11. React with required reagents and analyze spectrophotometrically for specific constituents	spectrophotometer	5		X	2b	"	4 hrs	1	"	"	
	12. Analyze plasma chromatographically for plasma proteins	chromatograph	5			2b	"	4 hrs	1	"	"	
	13. Record results	data sheets	8		X	2b	"	15 min	1	"	"	
	14. Dispose of samples	---	3		X	2c	"	10 min	1	"	"	
	15. Restore laboratory	---	3		X	2c	"	15 min	1	"	"	

## CREW ACTIVITY MATRIX

RESEARCH CLUSTER  
NO. 2-VB-3

[illegible]

EARTH ORBITAL EXPERIMENT PROGRAM  
AND REQUIREMENTS STUDY

SPACE BIOLOGY

RESEARCH CLUSTER-2-IN-1  
PRELIMINARY INVESTIGATIONS OF BIOLOGICAL PROCESSES,  
USING INVERTEBRATES

C-2-51'

RESEARCH CLUSTER SYNOPSIS-SPACE BIOLOGY  
2-IN-1

Preliminary Investigations of Biological Processes,  
Using Invertebrates

**1. Research Objectives**

Dividing the Space Biology Research Program into specimen-oriented research clusters permits a large number of specific research objectives to be undertaken within a particular experiment group. The present research cluster, which is oriented toward an investigation of the effects of weightlessness and orbit on the biological systems of invertebrates, includes experiments on aging, orientation, coordination, tidal and diurnal rhythms, genetic aberrations, and metabolism including enzyme and hormonal activities. As a consequence of the broad spectrum of research activities, the research cluster is more properly identified with Broad Objectives rather than with Supporting Specific Objectives. The NASA-defined Scientific and Technological Objectives in Space Biology to which experiments on invertebrates may be expected to contribute are:

1. To understand the role of gravity in life processes and the capability of living organisms to adapt to gravitational changes.
2. To understand the role of time in biology, including the effects of time-varying environmental parameters on biological rhythms and aging.

The critical issues related to the objectives of this research cluster are most easily referable to the three-dimensional matrix from which the various issues were derived (Chart 2-1, Appendix A). The taxonomy axis is, by nature of this research division, restricted to invertebrates. The environment axis will be restricted through experimental controls, to the effects of zero-g. On the axis dealing with life processes, most of the indicated areas are legitimate candidates for research on invertebrates. Studies on rhythms, genetics, and natural behavior will be stressed, and studies on specific physiological systems and behavioral studies involving learning and conditioned behavior will be primarily relegated to other research areas.

The specific experiment objective associated with this research cluster is the investigation of the effects of weightlessness and orbit on the biological systems of invertebrates, including changes in endogenous rhythms, behavior, genetics, and metabolism.

**2. Background and Current Status**

A large number of invertebrates were used in very early suborbital and short orbital flights. Most experiments were secondary to the testing of the launch vehicle and produced very little valid data. The first space program designed specifically for research in space

biology was the Biosatellite Program. Biosatellite II, flown in 1967, carried onboard Drosophila, flour beetles, and Habrobracon, from which valuable information was derived. The interaction of the space environment and radiation on both reproductive cell damage and somatic damage in the Drosophila, the effect of irradiation in space on the flour beetle, and the nutritional response of Habrobracon were investigated.

Skylab A is presently scheduled to investigate potential changes in the circadian rhythm of Drosophila in experiment S-072. It is expected that the results of this experiment will be verified on subsequent flights.

Among the studies that the American Institute of Biological Sciences has recommended to NASA, the experiments in invertebrates ranked numerically high. Seven experiments in the area of behavior, six in the area of morphogenesis, and two each in the areas of geosensitivity, metabolism, and biorhythms were suggested by the various councils. Experiments on the Drosophila were given the highest priority in all applicable research areas.

### **3. Description of Research**

Experiments for investigating biological processes in invertebrates in the space environment potentially include a large number and broad variety of observations from simple photographic, enumeration, separation, and preservation tasks on Drosophila to extremely difficult and sophisticated measurements on metabolic pathways and enzyme activities.

The sequencing of experiments is based on both experimental design and expediency. The common scientific approach of initial general observations, followed by more complete examination of those aspects showing alterations, and concluding in detailed studies of mechanisms is quite appropriate to space biology. Additionally, the recognition of the limitations of crew size, available time, and specialized skills in early spaceflights leads to the design of experiments which, at first, require minimal crew involvement; and, later, extensive crew involvement. These two approaches are quite compatible and are readily combined in program definition.

The preliminary phase (Phase I), Experiment Group 2-IN-1, of the invertebrate experiment program will utilize only man's ability to maintain the biological specimens and to make meaningful observations. Included in this phase are experiments recommended for inclusion in the Skylab B and Early Space Station programs, as well as aspects of experiments recommended for the Mid Space Station program. These experiments involve the study of Drosophila behavior and life-cycle phenomena and the verification of the results of its circadian rhythm in space, which was first investigated in Skylab A. Also visual counting of living

and dead specimens and preservation of houseflies in aging studies, photography of color changes in fiddler crabs related to tidal rhythms, visual observation and counting of beetles with abnormalities associated with embryogenesis and development, motion pictures and visual observation of Drosophila locomotion, visual observation and sorting of Habrobracon, and motion pictures of web building by spiders. These experiments are designated 3 - 106, 3 - 125, 3 - 220, 3 - 223, 3 - 227, 3 - 237, 3 - 240, 3 - 241 and are detailed in Phase II of a Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA CR 111794, as well as summarized in Appendix H of this report.

Experiments conducted during the intermediate phase (Phase II), Experiment Group 2-IN-2, which are characterized by research on previously observed changes and increased astronaut participation, are exemplified by experiments 3-220, 3-223, 3-227, 3-237, 3-240, and 3-241 mentioned in the program for the preliminary phase. In this phase, onboard comparisons between invertebrates in zero-g and invertebrates in artificial-g (which is produced by an onboard biocentrifuge) is recommended. Dissection, tissue preparation, and microscopic examinations will also be required and possibly some preliminary observations on metabolic activities, using radioactive tags on whole specimens or simple homogenetes. For the research conducted during the intermediate phase, laboratory specialists will be required. These specialists should be trained, experienced biological scientists (technologists) alternately trained as astronauts. The full-time participation of two such individuals should be anticipated in this phase of the Space Biology program.

Techniques used in the advanced-phase (Phase III) experiments, Experiment Group 2-IN-3, which will be directed toward the investigation of mechanisms, are sophisticated, and extensive astronaut participation will be required. Insofar as changes cannot as yet be predicted, no specific experiments can be assumed for the determination of mechanisms. Regardless of the details of each, the experiments will undoubtedly involve studies at the subcellular level, including investigation of metabolic pathways and transport mechanisms. Activities will include the isolation of enzymes, the reaction of tagged substrates with the enzyme systems (substrate tagging usually occurring before flight) and the determination of enzyme activity by the measurement of isotope disappearance from the substrate or its appearance from the products of the reaction. Such studies require advanced instrumentation, complex and precise techniques and fully experienced investigators. It would be desirable for the principal investigator to be onboard for the conducting of the experiments. In his absence, a highly qualified scientist experienced in the field should perform the experiment. He should be assisted by at least two experienced technologists. The duties of this team should be essentially restricted to space biology research.

#### 4. Impact on Spacecraft

The major impact of experiments during the preliminary phase will be produced by the requirements of the experimental modules. The Drosophila module is self-contained, maintaining the flies at earth ambient pressure, 25° C, 75-percent relative humidity, and 12-hr light-dark cycles. It also provides an internal camera for photographic coverage. The module weighs 40 lb, occupies 2 cu ft, and requires 50 w for 12 hr per day (light) and 10 w for 12 hr per day (dark). It outputs data from the various environmental sensors but requires a recording capability from the spacecraft system.

The experimental modules associated with the other organisms would be expected to have an impact on the station similar to that of the Drosophila module.

A minimal amount of laboratory space and equipment will be required for inspecting, sorting, and preserving the specimens. A dissecting microscope would be the major item of equipment required for this activity.

Research during the intermediate phase will continue to require self-contained modules for the invertebrates, the number of modules depending on the number of experiments selected for a specific mission. The major item of additional equipment will be the onboard biocentrifuge. Design requirements for this biocentrifuge have as yet not been specified, but it is expected to approach the human centrifuge in its capabilities, with a much more continuous running time. Its purpose would be to create an artificial-g equivalent to the Earth's unit gravity and would not, therefore, be required to produce high-g forces or high angular velocities. At an anticipated radius of 10 to 12 ft, rotational rates of 16 to 18 rpm would be required. The weight of the centrifuge would be about 1,000 lb and occupy about 550 cu ft. Certain laboratory facilities will also be required. A tissue-preparation laboratory will be needed, which should include an automatic tissue processor and staining system, a vacuum infiltration oven, a microtome, and a compound microscope with a built-in automatic camera. For preliminary biochemical and metabolic analysis, a spectrophotometer, a mass spectrometer, a gas chromatograph, and radiation detectors will be required. Much of this equipment will be common to other areas of space biology research.

During the advanced phase, experiments will continue to include modules for experimental subjects although the requirements for modular self-containment will be significantly reduced. Laboratory requirements will be increased to include facilities capable of permitting enzyme isolation, measuring cellular metabolism, and studying membrane phenomena and transport systems.



5. Required Supporting Technology Development

The development, design, construction, and testing of the experimental modules is the major task of required research and technology for preliminary-phase experiments. A number of subsystems must be designed and integrated for the proper overall functioning of the module. This work is already in progress at various NASA centers. Information derived from the design of the Biosatellite II modules will be of value in designing future modules. The major requirement for experiments conducted during the intermediate phase will be the design and construction of the biocentrifuge. Although no major studies are in progress on this item of equipment, much of the information generated in the NASA-General Dynamics Human Centrifuge Study will be applicable to the biocentrifuge. Some of the laboratory equipment required for intermediate-phase studies is planned for IMBLMS, the major exception being the equipment required for tissue preparation. This equipment requires development, testing, and integration. Research during the advanced phase is almost totally in the area of supporting research and technology. Conceptual studies must be undertaken in all cases to properly integrate the laboratories in the overall Space Station design.

Critical Issues Addressed by Research Cluster

2-IN-1

PRELIMINARY INVESTIGATIONS OF BIOLOGICAL PROCESSES,  
USING INVERTEBRATES

2.1.1.1.1.1.4

What is the effect of the space environment on the biosynthesis of glycogen?

2.1.1.1.1.1.7

What is the effect of the space environment on the biosynthesis of polysaccharides?

2.1.1.1.1.3.1

What is the effect of the space environment on the biosynthesis of acetyl coenzyme-A?

2.1.1.1.2.1.1

What is the effect of the space environment on the biosynthesis of chitin?

2.1.1.1.2.2.1.1

What is the effect of the space environment on the anabolism of calcium?

2.1.1.1.2.2.1.2

What is the effect of the space environment on the anabolism of phosphorus?

2.1.2.1.1

What is the effect of the space environment on aerobic mechanisms?

2.1.3.2.1.1

What is the effect of the space environment on the organism activity?

2.1.3.2.1.2

What is the effect of the space environment on feeding?

2.1.3.2.1.8

What is the effect of the space environment on cell division?

## 2.1.3.2.2.1

What is the effect of the space environment on tidal rhythms, as manifested by pumping rate of mussels?

## 2.1.3.2.2.2

What is the effect of the space environment on tidal rhythms, as manifested by amphipod (Synchelidiam) emergence from sand?

## 2.1.3.2.2.3

What is the effect of the space environment on tidal rhythms, as manifested by flatworm (Convoluta) emergence from sand?

## 2.1.3.2.2.5

What is the effect of the space environment on tidal rhythms, as manifested by crab respiratory oxygen intake?

## 2.1.3.2.2.6

What is the effect of the space environment on tidal rhythms, as manifested by amphipod (Talitrus) navigation?

## 2.1.3.2.2.7

What is the effect of the space environment on tidal rhythms, as manifested by crab activity?

## 2.1.3.2.2.8

What is the effect of the space environment on tidal rhythms, as manifested by crab color changes?

## 2.1.3.2.2.9

What is the effect of the space environment on tidal rhythms, as manifested by diatom migration to mud surface?

## 2.1.3.2.4.1

What is the effect of the space environment on lunar rhythms, as manifested by palolo worm spawning?

## 2.1.4.1.1.1.1

What is the effect of the space environment on fertilization?

## 2.1.4.1.1.1.2

What is the effect of the space environment on cleavage?

## 2.1.4.1.1.1.3.1.1

What is the effect of the space environment on the development of the ectoderm?

## 2.1.4.1.1.1.3.1.2

What is the effect of the space environment on the development of presumptive epidermis?

## 2.1.4.1.1.1.3.1.3

What is the effect of the space environment on the development of the neural plate?

2.1.4.1.1.1.3.1.4

What is the effect of the space environment on the development of the advanced ectodermal derivatives?

2.1.4.1.1.1.3.2.1

What is the effect of the space environment on the development of the mesoderm?

2.1.4.1.1.1.3.2.4

What is the effect of the space environment on the development of the nephrotome?

2.1.4.1.1.1.3.2.6

What is the effect of the space environment on the development of the advanced mesodermal derivatives?

2.1.4.1.1.1.3.3.1

What is the effect of the space environment on the development of endoderm?

2.1.4.1.1.1.3.3.2

What is the effect of the space environment on the development of the advanced endodermal derivatives?

2.1.4.1.1.1.3.4

What is the effect of the space environment on transformation?

2.1.4.2.1.1

What is the effect of the space environment on the frequency of lethal mutations?

2.1.4.2.1.2

What is the effect of the space environment on the frequency of conditional-lethal mutations?

2.1.4.2.1.3

What is the effect of the space environment on the frequency of nonlethal mutations?

2.1.5.1.1.1.1.1

What is the effect of the space environment on the exteroceptive nerves?

2.1.5.1.1.1.2.1

What is the effect of the space environment on the neuromotor nerves?

2.1.5.1.1.2.2.1

What is the effect of the space environment on the motor control centers?

2.1.5.1.2.2.3.1

What is the effect of the space environment on the response of skeletal support to external stress?

2.1.5.1.5.1

What is the effect of the space environment on the senescence?

2.1.5.1.5.2

What is the effect of the space environment on the life span?

2.1.5.2.1.1

What is the effect of the space environment on the cutaneous sensation?

2.1.5.2.5.1

What is the effect of the space environment on the drives?

**EARTH ORBITAL EXPERIMENT PROGRAM  
AND REQUIREMENTS STUDY**

**SPACE BIOLOGY**

**RESEARCH CLUSTER-2-IN-2  
INTERMEDIATE INVESTIGATIONS OF BIOLOGICAL PROCESSES,  
USING INVERTEBRATES**

*C-2-60*

Critical Issues Addressed by Research Cluster

2-IN-2

INTERMEDIATE INVESTIGATIONS OF BIOLOGICAL PROCESSES,  
USING INVERTEBRATES

2.1.1.1.1.1.4

What is the effect of the space environment on the biosynthesis of glycogen?

2.1.1.1.1.1.7

What is the effect of the space environment on the biosynthesis of other polysaccharides?

2.1.1.1.1.2.1

What is the effect of the space environment on the biosynthesis of creatine phosphate?

2.1.1.1.1.3.1

What is the effect of the space environment on the biosynthesis of acetyl coenzyme-A?

2.1.1.1.2.1.1

What is the effect of the space environment on the biosynthesis of chitin?

2.1.1.1.2.2.1.1

What is the effect of the space environment on the anabolism of calcium?

2.1.1.1.2.2.1.2

What is the effect of the space environment on the anabolism of phosphorus?

2.1.1.1.2.2.1.3

What is the effect of the space environment on the anabolism of other skeletal minerals?

2.1.1.1.2.2.2.1

What is the effect of the space environment on the anabolism of sodium?

2.1.1.1.2.2.2.2

What is the effect of the space environment on the anabolism of potassium?

RESEARCH CLUSTER  
NO.2-IN-2

2.1.1.1.2.2.2.3

What is the effect of the space environment on the anabolism of chloride?

2.1.1.1.2.2.2.4

What is the effect of the space environment on the anabolism of other nonskeletal minerals?

2.1.1.1.2.3.1

What is the effect of the space environment on the biosynthesis of muscle protein?

2.1.1.1.2.3.3

What is the effect of the space environment on the biosynthesis of other proteins?

2.1.1.1.3.1.2.3

What is the effect of the space environment on the biosynthesis of gonadal hormones?

2.1.1.1.3.1.2.7

What is the effect of the space environment of the biosynthesis of other hormones?

2.1.1.1.3.2.1.2

What is the effect of the space environment on the biosynthesis of DNA?

2.1.1.3.2.1

What is the effect of the space environment on the glycolytic processes?

2.1.1.3.2.2

What is the effect of the space environment on the amino acid pools?

2.1.1.3.3.2

What is the effect of the space environment on the catabolism of triglycerides?



2.1.1.3.4.1.1

What is the effect of the space environment on carbohydrate catabolism through the pentose phosphate shunt?

2.1.1.3.4.1.2

What is the effect of the space environment on carbohydrate catabolism through the TCA cycle?

2.1.1.3.4.2.1

What is the effect of the space environment on carbohydrate catabolism through the glycolytic mechanisms?

2.1.1.3.4.2.2

What is the effect of the space environment on carbohydrate catabolism through the nonglycolytic mechanisms?

2.1.2.1.1.1.1

What is the effect of the space environment on the reaction mediated by the enzyme, pyruvic oxidase?

2.1.2.1.1.1.2

What is the effect of the space environment on the reaction mediated by the isocitric enzyme?

2.1.2.1.1.1.3

What is the effect of the space environment on the reaction mediated by the enzyme, alpha ketoglutarate oxidase?

2.1.2.1.1.1.4

What is the effect of the space environment on the reaction mediated by the enzyme, succinyl thiokinase?

2.1.2.1.1.1.5

What is the effect of the space environment on the reaction mediated by the enzyme, succinic dehydrogenase?

2.1.2.1.1.1.6

What is the effect of the space environment on the reaction mediated by the enzyme, malic dehydrogenase?

2.1.2.1.1.3.1

What is the effect of the space environment on the reaction mediated by the enzyme, glucose-6-phosphate dehydrogenase?

2.1.2.1.1.3.2

What is the effect of the space environment on the reaction mediated by the enzyme, 6-phospho gluconic acid dehydrogenase?

2.1.2.1.1.4.1

What is the effect of the space environment on the reaction mediated by the enzyme, acyl dehydrogenase?

2.1.2.1.1.4.2

What is the effect of the space environment on the reaction mediated by the enzyme, hydroxyacyl dehydrogenase?

2.1.2.1.1.5.1

What is the effect of the space environment on the reaction mediated by glutamic acid dehydrogenase?

2.1.2.1.1.6.1

What is the effect of the space environment on the reaction mediated by the transaminases?

2.1.2.1.2.1.1

What is the effect of the space environment on the reaction mediated by the enzyme, phosphoglyceraldehyde dehydrogenase?

2.1.2.1.2.1.2

What is the effect of the space environment on the reaction mediated by the enzyme, phosphoglyceryl kinase?

2.1.2.1.2.1.3

What is the effect of the space environment on the reaction mediated by the enzyme, pyruvic oxidase?

2.1.3.2.6.8

What is the effect of the space environment on rhythms which are independent of environmental periodicities, as exemplified by glycolytic enzyme oscillations?

2.1.3.2.7.2.1

What is the effect of the space environment on metabolic and/or energetic alterations of rhythm resulting from nuclear control?

2.1.3.2.7.2.3

What is the effect of the space environment on metabolic and/or energetic alterations of rhythm resulting from interactions among subcellular organelles?

2.1.4.2.1.3.1

What is the effect of the space environment on nonlethal mutations manifested as structural abnormalities?

2.1.4.2.1.3.2

What is the effect of the space environment on nonlethal mutations manifested as biochemical abnormalities?

2.1.4.2.1.3.3

What is the effect of the space environment on nonlethal mutations manifested as chromosomal abnormalities?

2.1.4.2.2.2

What is the effect of the space environment on genetic information exchange through epigenetic systems?

2.1.4.2.2.3.1

What is the effect of the space environment on genetic information exchange through the processes of transduction?

2.1.4.2.2.3.2

What is the effect of the space environment on genetic information exchange through the processes of transformation?

2.1.5.1.2.1.1.1.1

What is the effect of the space environment on locomotor muscles?

2.1.5.1.2.1.1.1.2

What is the effect of the space environment on support muscles?

2.1.5.1.2.2.1.1

What is the effect of the space environment on musculo-skeletal attachments?

2.1.5.1.2.2.1.2

What is the effect of the space environment on skeletal articulation?

2.1.5.1.2.2.2.1

What is the effect of the space environment on skeletal protection of specific organs?

2.1.5.1.2.2.2.2

What is the effect of the space environment on skeletal protection of general body areas?

2.1.5.1.3.1.3.1

What is the effect of the space environment on the transport of respiratory gases, as manifested in the respiratory pigments?

2.1.5.1.3.2.1.1

What is the effect of the space environment on internal pressure, as manifested in the regulatory mechanisms?

2.1.5.1.3.2.1.4

What is the effect of the space environment on internal pressure, as manifested in the osmotic pressure?

2.1.5.1.3.3.2.1.5

What is the effect of the space environment on internal pressure, as manifested in the active transport processes?

2.1.5.1.4.2.1

What is the effect of the space environment on digestion of nutrients?

2.1.5.1.4.2.2

What is the effect of the space environment on absorption of nutrients?

2.1.5.1.4.7.1

What is the effect of the space environment on oogenesis?

2.1.5.1.4.7.2

What is the effect of the space environment on spermatogenesis?

2.1.5.3.1.1.2.3.1

What is the effect of the space environment on disease transmission for different numbers of animals per chamber?

2.1.5.3.1.1.2.3.2

What is the effect of the space environment on state of susceptibility or resistance?

2.1.5.3.1.1.2.3.3

What is the effect of the space environment on disease transmission for different levels of confined space per animal?

**EARTH ORBITAL EXPERIMENT PROGRAM  
AND REQUIREMENTS STUDY**

**SPACE BIOLOGY**

**RESEARCH CLUSTER-2-IN-3  
ADVANCED INVESTIGATIONS OF BIOLOGICAL PROCESSES,  
USING INVERTEBRATES**

*C-26b*

Critical Issues Addressed by Research Cluster  
2-IN-3

ADVANCED INVESTIGATIONS OF BIOLOGICAL PROCESSES,  
USING INVERTEBRATES

- 2.1.1.1.1.1.4  
What is the effect of the space environment on the biosynthesis of glycogen?
- 2.1.1.1.1.1.7  
What is the effect of the space environment on the biosynthesis of other polysaccharides?
- 2.1.1.1.1.2.1  
What is the effect of the space environment on the biosynthesis of creatine phosphate?
- 2.1.1.1.1.3.1  
What is the effect of the space environment on the biosynthesis of acetyl coenzyme-A?
- 2.1.1.1.2.1.1  
What is the effect of the space environment on the biosynthesis of chitin?
- 2.1.1.1.2.1.7  
What is the effect of the space environment on the biosynthesis of other polysaccharides?
- 2.1.1.1.2.2.1.1  
What is the effect of the space environment on the anabolism of calcium?
- 2.1.1.1.2.2.1.2  
What is the effect of the space environment on the anabolism of phosphorus?
- 2.1.1.1.2.2.1.3  
What is the effect of the space environment on the anabolism of other skeletal minerals?
- 2.1.1.1.2.2.2.1  
What is the effect of the space environment on the anabolism of sodium?

2.1.1.1.2.2.2.2

What is the effect of the space environment on the anabolism of potassium?

2.1.1.1.2.2.2.3

What is the effect of the space environment on the anabolism of chloride?

2.1.1.1.2.2.2.4

What is the effect of the space environment on the anabolism of other nonskeletal minerals?

2.1.1.1.2.3.1

What is the effect of the space environment on the biosynthesis of muscle protein?

2.1.1.1.2.3.3

What is the effect of the space environment on the biosynthesis of other proteins?

2.1.1.1.3.2.1.1.1

What is the effect of the space environment on the biosynthesis of ATP?

2.1.1.1.3.2.1.1.2

What is the effect of the space environment on the biosynthesis of UTP?

2.1.1.1.3.2.1.1.3

What is the effect of the space environment on the biosynthesis of GTP?

2.1.1.1.3.2.1.1.4

What is the effect of the space environment on the biosynthesis of other nucleotides?

2.1.1.1.3.2.1.2

What is the effect of the space environment on the biosynthesis of DNA?

2.1.1.1.3.2.1.3.1

What is the effect of the space environment on the biosynthesis of messenger RNA?

2.1.1.1.3.2.1.3.2

What is the effect of the space environment on the biosynthesis of transfer RNA?

2.1.1.1.3.2.1.3.3

What is the effect of the space environment on the biosynthesis of ribosomal RNA?

2.1.1.1.3.2.1.3.4

What is the effect of the space environment on the biosynthesis of other RNA's?

2.1.1.1.3.2.2

What is the effect of the space environment on the biosynthesis of histones?

3.1.1.1.3.3.1

What is the effect of the space environment on the biosynthesis of coenzyme-A?

2.1.1.1.3.3.2

What is the effect of the space environment on the biosynthesis of flavins?

2.1.1.1.3.3.3

What is the effect of the space environment on the biosynthesis of biotin?

2.1.1.1.3.3.4

What is the effect of the space environment on the biosynthesis of nicotinic acid?

2.1.1.1.3.3.5

What is the effect of the space environment on the biosynthesis of folic acid?

2.1.1.1.3.3.6

What is the effect of the space environment on the biosynthesis of cobamide coenzyme?

2.1.1.1.3.3.7

What is the effect of the space environment on the biosynthesis of thiamine cocarboxylase?

2.1.1.1.3.3.8

What is the effect of the space environment on the biosynthesis of other enzyme cofactors?

2.1.1.2.1.2.3

What is the effect of the space environment on the metabolic control functions of gonadal hormones?

2.1.1.2.1.2.9

What is the effect of the space environment on the metabolic control functions of other hormones?

2.1.1.3.1.1.1

What is the effect of the space environment on the breakdown of ATP?

2.1.1.3.1.1.2

What is the effect of the space environment on the breakdown of UTP?



2.1.1.3.1.1.3

What is the effect of the space environment on the breakdown of ITP?

2.1.1.3.1.1.4

What is the effect of the space environment on the breakdown of GTP?

2.1.1.3.1.2.1

What is the effect of the space environment on the breakdown of adenosine?

2.1.1.3.1.2.2

What is the effect of the space environment on the breakdown of cytidine?

2.1.1.3.1.2.3

What is the effect of the space environment on the breakdown of inosine?

2.1.1.3.1.2.4

What is the effect of the space environment on the breakdown of guanosine?

2.1.1.3.1.3.1.1

What is the effect of the space environment on the breakdown of adenine?

2.1.1.3.1.3.1.2

What is the effect of the space environment on the breakdown of hypoxanthine?

2.1.1.3.1.3.1.3

What is the effect of the space environment on the breakdown of xanthine?

2.1.1.3.1.3.1.4

What is the effect of the space environment on the breakdown of guanine?

2.1.1.3.1.3.2.1

What is the effect of the space environment on the breakdown of uracil?

2.1.1.3.1.3.2.2

What is the effect of the space environment on the breakdown of cytosine?

2.1.1.3.1.3.2.3

What is the effect of the space environment on the breakdown of thymine?

2.1.1.3.1.4.1

What is the effect of the space environment on the breakdown of ribose?

2.1.1.3.1.4.2

What is the effect of the space environment on the breakdown of deoxyribose?

2.1.1.3.2.1

What is the effect of the space environment on glycolytic processes?

2.1.1.3.2.2

What is the effect of the space environment on amino acid pools?

2.1.1.3.2.3

What is the effect of the space environment on ketogenic processes?

2.1.1.3.3.1.1

What is the effect of the space environment on the beta-oxidation of fatty acids?

2.1.1.3.3.1.2

What is the effect of the space environment on the omega-oxidation of fatty acids?

2.1.1.3.3.2

What is the effect of the space environment on the catabolism of triglycerides?

2.1.1.3.4.1.1

What is the effect of the space environment on carbohydrate catabolism through the pentose phosphate shunt?

2.1.1.3.4.1.2

What is the effect of the space environment on carbohydrate catabolism through the TCA cycle?

2.1.1.3.4.2.1

What is the effect of the space environment on carbohydrate catabolism through the glycolytic mechanisms?

2.1.1.3.4.2.2

What is the effect of the space environment on carbohydrate catabolism through the nonglycolytic mechanisms?

2.1.2.1.1.1.1

What is the effect of the space environment on the reaction mediated by the enzyme, pyruvic oxidase?

2.1.2.1.1.1.2

What is the effect of the space environment on the reaction mediated by the isocitric enzyme?

2.1.2.1.1.1.3

What is the effect of the space environment on the reaction mediated by the enzyme, alpha ketoglutarate oxidase?

2.1.2.1.1.1.4

What is the effect of the space environment on the reaction mediated by the enzyme succinyl thiokinase?

2.1.2.1.1.1.5

What is the effect of the space environment on the reaction mediated by the enzyme, succinic dehydrogenase?

2.1.2.1.1.1.6

What is the effect of the space environment on the reaction mediated by the enzyme, malic dehydrogenase?

2.1.2.1.1.2.1

What is the effect of the space environment on the formation of ATP at the NAD/FAD crossover point?

2.1.2.1.1.2.2

What is the effect of the space environment on the formation of ATP at the FAD/cytochrome-C crossover point?

2.1.2.1.1.2.3

What is the effect of the space environment on the formation of ATP at the cytochrome C/cytochrome oxidase crossover point?

2.1.2.1.1.3.1

What is the effect of the space environment on the reaction mediated by the enzyme, glucose-6-phosphate dehydrogenase?

2.1.2.1.1.3.2

What is the effect of the space environment on the reaction mediated by the enzyme, 6-phospho gluconic acid dehydrogenase?

2.1.2.1.1.4.1

What is the effect of the space environment on the reaction mediated by the enzyme, acyl dehydrogenase?

2.1.2.1.1.4.2

What is the effect of the space environment on the reaction mediated by the enzyme, hydroxyacyl dehydrogenase?

2.1.2.1.1.5.1

What is the effect of the space environment on the reaction mediated by glutamic acid dehydrogenase?

2.1.2.1.1.6.1

What is the effect of the space environment on the reaction mediated by the transaminases?

2.1.2.1.2.1.1

What is the effect of the space environment on the glycolitic reaction mediated by the enzyme, phosphoglyceraldehyde dehydrogenase?

2.1.2.1.2.1.2

What is the effect of the space environment on the glycolitic reaction mediated by the enzyme, phosphoglyceryl kinase?

2.1.2.1.2.1.3

What is the effect of the space environment on the glycolitic reaction mediated by the enzyme, pyruvic oxidase?

2.1.3.2.7.2.1

What is the effect of the space environment on metabolic and/or energetic alterations of rhythms resulting from nuclear control?

2.1.3.2.7.2.2

What is the effect of the space environment on metabolic and/or energetic alterations of rhythms resulting from oscillations in membrane properties?

2.1.3.2.7.2.3

What is the effect of the space environment on metabolic and/or energetic alterations of rhythms resulting from interactions among subcellular organelles?

2.1.3.2.7.2.4

What is the effect of the space environment on metabolic and/or energetic alterations of rhythms resulting from the indicator process?

2.1.3.2.7.2.5

What is the effect of the space environment on metabolic and/or energetic alterations of rhythms resulting from the basic (time-reference) oscillator?

2.1.4.1.1.1.3

What is the effect of the space environment on metabolic and/or energetic alterations of rhythms resulting from differentiation?

2.1.4.2.1.2

What is the effect of the space environment on the frequency of conditional-lethal mutations?

2.1.4.2.1.3

What is the effect of the space environment on the frequency of nonlethal mutations?

2.1.4.2.2.3.1

What is the effect of the space environment on genetic information exchange through the processes of transduction?

2.1.4.2.2.3.2

What is the effect of the space environment on genetic information exchange through the process of transformation?

2.1.4.2.3.1.1

What is the effect of the space environment on DNA, as manifested by induction?

2.1.4.2.3.1.2

What is the effect of the space environment on DNA, as manifested by repression?

2.1.5.1.3.2.1.5

What is the effect of the space environment on internal pressure, as manifested in the active transport processes?

2.1.5.1.5.2

What is the effect of the space environment on life span?

2.1.5.3.4.1

What is the effect of the space environment on factors that alter host defenses?

2.1.5.3.4.2

What is the effect of the space environment on factors that activate latent infections?

TABLE 1. LEGEND OF CODES USED IN CREW ACTIVITY MATRICES

Table 1 is an explanation of the codes used in the following matrices. The matrices summarize the inflight crew tasks required to conduct and support the research identified in the synopsis.

#### TYPE OF ACTIVITY

- |   |   |
|---|---|
| 0 - Not covered below                   | 5 - Conduct of experiment   |
| 1 - Experimental subject                | 6 - Evaluate intermediate results   |
| 2 - Spacecraft operations               | 7 - Direct observation of phenomena                                       |
| 3 - Preexperiment equipment preparation | 8 - Data handling   |
| 4 - Maintenance of equipment            | 9 - Communications; initiate and receive transmissions (telemetry, voice) |

#### CREW SKILL

- |                               |                      |
|-------------------------------|----------------------|
| 0 - No special skill required | 12 - Meteorology     |
| 1 - Medicine                  | 13 - Geography       |
| 2 - Biology                   | 14 - Cartography     |
| 3 - Physiology                | 15 - Hydrology       |
| 4 - Psychology                | 16 - Navigation      |
| 5 - Engineering               | 17 - Communications  |
| 6 - Astronomy                 | 18 - Radiology       |
| 7 - Physics                   | 19 - Instrumentation |
| 8 - Oceanography              | 20 - Photography     |
| 9 - Forestry                  | 21 - Astronaut       |
| 10 - Agriculture              | 22 - Other           |
| 11 - Geology                  |                      |

Each code includes the first one or two digits describing the discipline and a second code letter describing level of skill: A for highest skill level (requires professional training with degree or advanced degree in discipline such as M. D.); B for semiprofessional, the traditional technician level requiring several years of training; C for technician level which requires some special training.

C-2-73-a

CREW ACTIVITY MATRIX (Page 1 of 3)

RESEARCH CLUSTER NO.	TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE	CREW SKILL	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START	DURATION	TASK CONCURRENCY
2-IN-1 (a)	Drosophila Behavior and Life Cycle Phenomena									'74	90 Days	
(p.1 of 3)	(1) Remove empty capsules from refrigerator	Drosophila capsules and refrigerator.	3		X	2c	Once Only	15 Min.	1	"	—	
	(2) Inoculate agar with yeast	Capsules	3		X	2c	Weekly	1 Hour	1	"	90 Days	
	(3) Set up CO <sub>2</sub> anesthesia unit	Anesthetizer	3		X	2c	"	15 Min	1	"	"	
	(4) Anesthetize flies in egg containing capsules	"	5		X	2c	"	30	1	"	"	
	(5) Remove anesthetized flies, examine for sex	Hand Lens	5		X	2c	"	1 Hour	1	"	"	
	(6) Place males and females in separate capsules	Capsules	4		X	2c	"	30 Min	1	"	"	
	(7) Examine egg batch under microscope - Count eggs in batch.	Dissecting Microscope.	5		X	2c	"	4 Hrs.	1	"	"	
	(8) Record batch number and egg count.	Data Sheets	8		X	2c	"					
	(9) Maintain Colony - Observe eggs for hatching.	Capsules	4			2c	Daily	2 Hrs.	1	"	"	
	(10) Anesthetize offspring	Anesthetizer	5		X	2c	Weekly	30 Min	1	"	"	
	(11) Remove anesthetized flies, examine for sex.	Hand Lens	5		X	2c	"	1 Hr.	1	"	"	
	(12) Analyze for anatomical abnormalities	Dissecting Microscope	5		X	2c	"	2 Hrs.	1	"	"	
	(13) Separate some by sex into separate capsules	Capsules	5		X	2c	"	90 Min	1	"	"	
	(14) Place other males and females into common capsules.	"	4		X	2c	"	10 Min	1	"	"	
	(15) Sacrifice and preserve others.	Preservative and containers	5		X	2c	"	30 Min	1	"	"	
	(16) Repeat "4-15" for subsequent generations	—	—		X	2c	"	—				
	(17) Package live flies for return.	—	8		X	2c	Once Only	1 Hr.	1	"	—	
(b)	Drosophila Circadian Rhythms									'78		
	(1) Actuate instrumentation in zero "g" module.	Drosophila Modules.	3		X	2c	Once Only	15 Min	1	"	—	
	(2) Place control module on biocentrifuge and set rpm.	Biocentrifuge	3		X	2c	"	30 Min	1	"	—	
	(3) Actuate control module instrument and start centrifuge.	Modules and Centrifuge	3		X	2c	"	15 Min	1	"	—	
	(4) Stop Centrifuge	Centrifuge	3		X	2c	"	10 Min	1	"	—	
	(5) Disconnect both modules and package for return.	Modules	3		X	2c	"	2 Hrs.	1	"	—	
	(6) Monitor environmental parameter display from modules	Modules	4			2c	Daily	10 Min	1	"	90 Days	

(Page 2 of 3)

RESEARCH CLUSTER NO.	TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE	CREW SKILL	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START	DURATION	TASK CONCURRENCY
2-IN-1 (c) (p.2 of 3)	Web Building of Spiders. Tasks identical to 2IN-1(b), <i>Drosophila</i> Circadian Rhythms.	_____	—	_____	—	2c	—	—	1	'78	90 Days	
(d)	Cockroach Circadian Rhythms. Tasks identical to 2-IN-1(b), <i>Drosophila</i> Circadian Rhythms.	_____	—	_____	—	2c	—	—	1	"	90 Days	
(e)	Tidal Rhythms of the Fiddler Crab. Tasks identical to 2-IN-1(b), <i>Drosophila</i> Circadian Rhythms.	_____	—	_____	—	2c	—	—	1	"	90 Days	
(f)	Habrobracon Genetics.									'76		
	(1) Initiate Module Instrumentation	Habrobracon Modules.	3		X	2c	Monthly	15 Min.	1	"	90 Days	
	(2) Monitor modules for evidence of offspring.	Modules	4		X	2c	Daily	10 Min	1	"	"	
	(3) Set up anesthetizer	Anesthetizer	3		X	2c	Monthly	10 Min	1	"	"	
	(4) Anesthetize Colony	"	5		X	2c	"	30 Min	1	"	"	
	(5) Examine offspring for genetic abnormalities.	Dissecting Microscope	5		X	2c	"	2 Hrs.	1	"	"	
	(6) Recombine adults as specified	Capsules	4		X	2c	"	90 Min	1	"	"	
	(7) Repeat "2 through 5".	_____	—		X	2c	—	—		"	—	
(g)	Beetle Development									'78		
	(1) Initiate module instrumentation	Modules	3		X	2c	Once Only	15 Min	1	"	90 Days	
	(2) Make visual count of dead offspring	Modules	5		X	2c	Daily	5 Min	1	"	"	
	(3) Remove and preserve dead offspring.	Preservative and containers	4		X	2c	Once Only	90 Min	1	"	—	
	(4) Sacrifice and preserve remaining offspring.	Preservative	4		X	2c	"	90 Min	1	"	—	
	(5) Examine offspring for wing abnormalities.	Hand Lens	5		X	2c	"	2 Hrs.	1	"	—	
	(6) Prepare and stain slides of germ cells.	Dissecting Microscope & Micromanipulator	5			2b	"	4 Hrs.	1	"	—	
		Slide Processor.										
	(7) Examine and analyze slides for cell abnormalities.	Compound Microscope	5		X	2b	"	4 Hrs.	1	"	—	
	(8) Package slides and preserved specimens for return.	Specimen Containers	8		X	2c	"	2 Hrs.	1	"	—	



C-2-76

RESEARCH CLUSTER  
NO. 2-IN-2

C-2-77

RESEARCH CLUSTER  
NO. 2-IN-3

### ACTIVITY MATRIX

[illegible]

EARTH ORBITAL EXPERIMENT PROGRAM  
AND REQUIREMENTS STUDY

SPACE BIOLOGY

RESEARCH CLUSTER-2-P/T-1

PRELIMINARY INVESTIGATIONS OF BIOLOGICAL PROCESSES,  
USING UNICELLULAR SPECIMENS (PROTISTS AND TISSUE CULTURES)

C-2-79

RESEARCH CLUSTER  
SYNOPSIS--SPACE BIOLOGY

2-P/T-1

Preliminary Investigations of Biological Processes, Using  
Unicellular Specimens (Protists and Tissue Cultures)

**1. Research Objectives**

Dividing the Space Biology Research Program into specimen-oriented research clusters permits a large number of specific research objectives to be undertaken within a particular experiment group. The present research cluster, which is oriented toward an investigation of biological processes in protists and tissue culture, includes observations of growth characteristics, cytopathy, mutation frequency, mutation characteristics, reproduction, host-parasite relationships, host defense mechanisms, and animal susceptibility to pathogenes. As a consequence of the broad spectrum of research activities, the research cluster is more properly identified with Broad objectives rather than with Supporting Specific Objectives. The NASA-defined Scientific and Technological Objectives in Space Biology to which experiments on protists and tissue cultures may be expected to contribute are:

1. To understand the role of gravity in life processes and the capability of living organisms to adapt to gravitational changes.
2. To understand the role of time in biology, including the effects of time-varying environmental parameters on biological rhythms and aging.

The critical issues related to the objectives of this research cluster are most easily referable to the three-dimensional matrix from which the various issues were derived (Chart 2-1, Appendix A). The taxonomy axis is, by nature of this research division, restricted to protists, with the addition of tissue cultures potentially common to animals and plants. The environment axis will be restricted, through experimental controls, to the effects of zero-g. The axis dealing with life processes will include all categories excepting those concerned with physiological and behavioral organization, the critical issues in these latter categories being restricted to organisms with a more complex organization than that of the protists. In the other life processes applicable to the protists, the critical issues that are specifically directed toward a higher organism will be disregarded.

The specific experiment objectives associated with this research cluster are:

1. To survey selected processes in microorganisms and tissue cultures to determine the presence of abnormalities caused by weightlessness.

2. To gain insight into the effect of weightlessness and other spaceflight factors on the host-parasite relationship.
3. To determine the mechanisms responsible for alterations in life processes caused by weightlessness.

## 2. Background and Current Status

A number of the experiments on Biosatellite II used protists and tissues as experimental subjects: the extensively studied mold, Neurospora crassa; lysogenic bacteria; the egg of the frog, Rana pipiens; and the amoeba, Pelomyxa carolinensis. The observed characteristics of the frog eggs and the amoeba remained essentially unchanged in the space environment. The bacteria appeared to grow more rapidly in weightlessness; however, it remains controversial as to whether this increase in growth rate is the result of more rapid anabolic reactions or simply better dispersion of the bacteria in the fluid media. A circadian rhythm in growth and spore discharge is observed in the "clock" mutant of Neurospora, and it is not known whether the timing mechanism is of terrestrial or endogenous origin.

The Skylab A experiment program will include an experiment, S-015, Zero-Gravity, Single Human Cells, in which the effects of weightlessness on human cells in tissue cultures will be observed. No experiments on protists are presently planned for this mission.

The types of research recommended for the intermediate and advanced phases (Phases II and III) have never been conducted in space, and much preflight development and study are necessary.

## 3. Description of Research

Experiments investigating biological processes in protists and tissue cultures in the space environment potentially include a large number and broad variety of observations ranging from the simple photographic recording of growth rings and conidial formation in Neurospora to the complex study of antigen processing by macrophages.

The sequencing of experiments is based on both experimental design and expediency. The common scientific approach of initial general observations, followed by more complete examination of those aspects showing alterations, and concluding in detailed studies of mechanisms is quite appropriate to space biology. Additionally, the recognition of the limitations of crew size, available time, and specialized skills in early spaceflights leads to the design of experiments which, at first, require minimal crew involvement; next, moderate crew involvement; and, later, extensive crew involvement. These two approaches are quite compatible and are readily combined in program definition.

The preliminary phase (Phase I), Research Cluster Group 2-P/T-1, of the protist and tissue-culture experiment program will utilize the crew for media preparation, culture transfer, organism identification, microscopy, photography and visual observations, and tasks in which the crewmen can be readily trained and for which the time requirements are not excessive. Included in this phase are experiments recommended for inclusion in the Skylab B and Early Space Station programs; the experiment on Neurospora is recommended for the Mid Space Station. These experiments involve the effects of weightlessness on frog-egg fertilization, on bacterial growth and morphology, on single human cells, and on growth and conidial formation rhythms of Neurospora. These experiments and their verification are designated 3-101, 3-107, 3-211, 3-216, 3-217, and 3-219 and are detailed in Phase II of A Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA CR 111794 and summarized in Appendix H of this report. Measurements and observations will include visual measurements and photography of colony size, colonial morphology, and conidial density, made with a small metric ruler and hand lens. Frog eggs and single human cells from tissue cultures will be examined with the microscope to determine cellular growth structure and organization. Optical density measurements will be performed on bacterial cultures for growth rates. In addition, selective media and culture preparation, DNA extraction, culture plating, and other bacterial genetic techniques associated with mutation frequency, transformation, and conjugation will be required. Additional crew activities include the observation of temperature fluctuations during incubation and the maintenance of tissue and bacterial cultures.

Experiments during the intermediate phase (Phase II), Research Cluster 2-P/T-2, involving research on host-parasite relationships and requiring significantly increased experimenter participation, are represented in part by experiments recommended for the Mid Space Station in the above-referenced biotechnology laboratory study. A study of aerosols in the spacecraft environment is an important aspect of this phase of the research, since bacterial dissemination and host penetration by means of aerosols are potentially great. Studies will be made of aerosol stability and the effects of particle size on stability dissemination rate, degree of penetration rate into the respiratory tract, microbial viability in aerosols, and the degree of infection from aerosol-borne bacteria. These studies will require air-particle sampling under various conditions, viable plate count by the Andersen method, and animal exposure, sacrifice, and examination for the presence of particles in the respiratory tract and for infections. In addition, colony counting and identification will also be performed on cultures of samples from monkeys or crew to determine quantitative and qualitative alterations in normal flora; the same measurements made on fecal samples before and after chemotherapy will

demonstrate flora repopulation of the gut in weightlessness. Finally, by agglutination or precipitation of serum antibodies and by optical density changes in tubes containing blood and lysozyme-susceptible cells, the immune reactions of the crew and vaccinated animals may be studied.

Crew activities will be extensive and will include the operations of the aerosolizer and air sampler, exposure of mice to aerosols and to bacteria-carrying aerosols, the sacrifice and examination of the animals, standard microbiological laboratory techniques, vaccination of experimental animals, blood sampling, and standard immunological observations. These activities will require the full-time participation of microbiological technicians as well as the involvement of one scientist-astronaut who is qualified to study infectious diseases.

Experiments during the advanced phase (Phase III), Research Cluster Group 2-P/T-3, will investigate selective factors responsible for normal floral shifts and the potential loss of protective functions which the normal flora provides. Immune mechanisms, such as the secretions of IgA, the thymus function, the lymphocyte transformation, the synthesis of immune globulins, and antigen processing by macrophages will be studied. Host defense mechanisms, such as mucocilliary function, phagocyte clearance, and peristalsis will be studied. Latent infections (primarily viral) will be included in the research cluster to determine factors that alter normal infection and cause activation of the infection. Crew participation will be extensive, including a full-time researcher, two scientists, and three technicians trained and experienced in microbiology and immunology.

#### 4. Impact on Spacecraft

Requirements for a well-equipped microbiological laboratory, including a sterilizer; all necessary equipment for media and plate preparation; a large incubator for culturing; and a colony counter, microscope, and optical densitometer for analysis will be common to experiments in all three phases. Preliminary-phase experiments, concerned with cultures of tissues and bacteria, will require little other equipment.

Experiments conducted during the intermediate phase will also require the aerosolizer and air-particle sampler, and will utilize the animal colonies developed in the vertebrate experiments of the preliminary phase. A small animal surgery, including autopsy and tissue preparation facilities and a blood chemistry laboratory, will be required in common with other areas of space biology research.

An extensive increase in facilities will be required for the advanced-phase experiments, which will provide a capability for the preparation of tissue grafts, chromatography, electrophoresis,



and radio-active tracer techniques, including the handling and counting of isotopes. The majority of these requirements are shared with the experiments conducted during the advanced phases of all other areas of space biology research.

#### 5. Required Supporting Technology Development

Most of the requirements of preliminary-phase research should be met by the developments planned for IMBLMS, these will include the development of a flight-qualified refrigerator-freezer, incubator, and sterilizer; the design and development of a Bunsen burner substitute; and the development and demonstration of fluid-handling and transfer techniques. For experiments, conducted during the intermediate phase, a rapid automated microbial identification system consisting of an automated ecology monitor and automated organism identification with a scanner and computer readout is required. The aerosolizer and particle sampler should be similar to existing models, but their operation in zero-g must be demonstrated and they must be otherwise flight-qualified.

Advanced-phase research is almost totally in the area of STD supporting research and technology. Conceptual studies must be undertaken in all cases to properly integrate the laboratories in the overall Space Facility design.

Critical Issues Addressed by Research Cluster

2-P/T-1

PRELIMINARY INVESTIGATIONS OF BIOLOGICAL PROCESSES,  
USING UNICELLULAR SPECIMENS (PROTISTS  
AND TISSUE CULTURES)

2.1.1.1.1.1.5

What is the effect of the space environment on the biosynthesis of dextran?

2.1.1.1.1.3.1

What is the effect of the space environment on the biosynthesis of acetyl coenzyme-A?

2.1.1.1.2.1.2

What is the effect of the space environment on the biosynthesis of cellulose?

2.1.1.1.2.1.3

What is the effect of the space environment on the biosynthesis of xylan?

2.1.1.1.2.1.4

What is the effect of the space environment on the biosynthesis of arabinose?

2.1.1.1.2.1.5

What is the effect of the space environment on the biosynthesis of mannose?

2.1.2.1.1

What is the effect of the space environment on aerobic mechanisms

2.1.3.1.1

What is the effect of the space environment on geotropic response?

2.1.3.1.2

What is the effect of the space environment on phototropic response?

2.1.3.1.3

What is the effect of the space environment on thermotropic response?

- 2.1.3.1.4  
What is the effect of the space environment on hydrotropic response?
- 2.1.3.1.5  
What is the effect of the space environment on chemotropic response?
- 2.1.3.1.6  
What is the effect of the space environment on the possibility of an interaction between two or more of the tropic responses?
- 2.1.3.2.1.6  
What is the effect of the space environment on circadian rhythms as manifested by rate of photosynthesis?
- 2.1.3.2.1.7  
What is the effect of the space environment on circadian rhythms as manifested by bioluminescent flashes, glow rhythm, and photosynthetic capacity in Gonyaulax?
- 2.1.3.2.1.8  
What is the effect of the space environment on circadian rhythms as manifested by cell division?
- 2.1.3.2.1.10  
What is the effect of the space environment on circadian rhythms as manifested by fungal growth and spore discharge?
- 2.1.3.2.1.11  
What is the effect of the space environment on circadian rhythms as manifested by odor production in Cestum?
- 2.1.3.2.2.4  
What is the effect of the space environment on tidal rhythms as manifested by Fucus respiratory rate?
- 2.1.3.2.5.3  
What is the effect of the space environment on annual rhythms of reproduction?
- 2.1.3.2.6.1  
What is the effect of the space environment on rhythms that are independent of environmental periodicities, as exemplified by beating of flagella and cilia?
- 2.1.4.1.2.1  
What is the effect of the space environment on motile sporophytes (zoospores)?

2. 1. 4. 1. 2. 2

What is the effect of the space environment on nonmotile sporophytes (sporangiophores)?

2. 1. 4. 2. 1. 1

What is the effect of the space environment on the frequency of lethal mutations?

2. 1. 4. 2. 1. 2

What is the effect of the space environment on the frequency of conditional-lethal mutations?

2. 1. 4. 2. 1. 3

What is the effect of the space environment on the frequency of nonlethal mutations?

2. 1. 4. 2. 1. 3. 1

What is the effect of the space environment on the frequency of structural abnormalities?

2. 1. 4. 2. 1. 3. 2

What is the effect of the space environment on the frequency of biochemical abnormalities?

2. 1. 4. 2. 1. 3. 3

What is the effect of the space environment on the frequency of chromosomal abnormalities?

2. 1. 4. 2. 2. 1. 1

What is the effect of the space environment on genetic information exchange through the process of sexduction?

2. 1. 4. 2. 2. 1. 2

What is the effect of the space environment on genetic information exchange through the process of conjugation?

EARTH ORBITAL EXPERIMENT PROGRAM  
AND REQUIREMENTS STUDY

SPACE BIOLOGY

RESEARCH CLUSTER-2-P/T-2  
INTERMEDIATE INVESTIGATIONS OF BIOLOGICAL PROCESSES,  
USING UNICELLULAR SPECIMENS (PROTISTS AND TISSUE CULTURES)

C-2-87

Critical Issues Addressed by Research Cluster

2-P/T-2

INTERMEDIATE INVESTIGATIONS OF BIOLOGICAL PROCESSES,  
USING UNICELLULAR SPECIMENS (PROTISTS  
AND TISSUE CULTURES)

2.1.1.1.1.1.1

What is the effect of the space environment on the biosynthesis of starch?

2.1.1.1.1.1.5

What is the effect of the space environment on the biosynthesis of dextran?

2.1.1.1.1.3.1

What is the effect of the space environment on the biosynthesis of acetyl coenzyme-A?

2.1.1.1.2.1.2

What is the effect of the space environment on the biosynthesis of cellulose?

2.1.1.1.2.1.3

What is the effect of the space environment on the biosynthesis of xylan?

2.1.1.1.2.1.4

What is the effect of the space environment on the biosynthesis of arabinose?

2.1.1.1.2.1.5

What is the effect of the space environment on the biosynthesis of mannose?

2.1.1.1.2.2.2

What is the effect of the space environment on the requirement of non-skeletal minerals for use as cofactors in anabolic reactions?

2.1.1.1.3.2.1.1.1

What is the effect of the space environment on the biosynthesis of ATP?

2.1.1.1.3.2.1.1.2

What is the effect of the space environment on the biosynthesis of UTP?

2.1.1.1.3.2.1.1.3

What is the effect of the space environment on the biosynthesis of GTP?

- 2.1.1.1.3.2.1.1.4  
What is the effect of the space environment on the biosynthesis of other nucleotides?
- 2.1.1.1.3.2.1.2  
What is the effect of the space environment on the biosynthesis of DNA?
- 2.1.1.1.3.2.1.3.1  
What is the effect of the space environment on the biosynthesis of messenger RNA?
- 2.1.1.1.3.2.1.3.2  
What is the effect of the space environment on the biosynthesis of transfer RNA?
- 2.1.1.1.3.2.1.3.3  
What is the effect of the space environment on the biosynthesis of ribosomal RNA?
- 2.1.1.1.3.2.1.3.4  
What is the effect of the space environment on the biosynthesis of other RNAs?
- 2.1.1.1.3.3.1  
What is the effect of the space environment on the biosynthesis of coenzyme-A?
- 2.1.1.1.3.3.2  
What is the effect of the space environment on the biosynthesis of flavins?
- 2.1.1.1.3.3.3  
What is the effect of the space environment on the biosynthesis of biotin?
- 2.1.1.1.3.3.4  
What is the effect of the space environment on the biosynthesis of nicotinic acid?
- 2.1.1.1.3.3.5  
What is the effect of the space environment on the biosynthesis of folic acid?
- 2.1.1.1.3.3.6  
What is the effect of the space environment on the biosynthesis of cobamide coenzyme?
- 2.1.1.1.3.3.7  
What is the effect of the space environment on the biosynthesis of thiamine cocarboxylase?

2.1.1.1.3.3.8

What is the effect of the space environment on the biosynthesis of other enzyme cofactors?

2.1.1.3.1.1.1

What is the effect of the space environment on the breakdown of ATP?

2.1.1.3.1.1.2

What is the effect of the space environment on the breakdown of UTP?

2.1.1.3.1.1.3

What is the effect of the space environment on the breakdown of ITP?

2.1.1.3.1.1.4

What is the effect of the space environment on the breakdown of GTP?

2.1.1.3.1.2.1

What is the effect of the space environment on the breakdown of adenosine?

2.1.1.3.1.2.2

What is the effect of the space environment on the breakdown of cytidine?

2.1.1.3.1.2.3

What is the effect of the space environment on the breakdown of inosine?

2.1.1.3.1.2.4

What is the effect of the space environment on the breakdown of guanosine?

2.1.1.3.1.3.1.1

What is the effect of the space environment on the breakdown of adenine?

2.1.1.3.1.3.1.2

What is the effect of the space environment on the breakdown of hypoxanthine?

2.1.1.3.1.3.1.3

What is the effect of the space environment on the breakdown of xanthine?

2.1.1.3.1.3.1.4

What is the effect of the space environment on the breakdown of guanine?



2. 1. 1. 3. 1. 3. 2. 1

What is the effect of the space environment on the breakdown of uracil?

2. 1. 1. 3. 1. 3. 2. 2

What is the effect of the space environment on the breakdown of cytosine?

2. 1. 1. 3. 1. 3. 2. 3

What is the effect of the space environment on the breakdown of thymine?

2. 1. 1. 3. 1. 4. 1

What is the effect of the space environment on the breakdown of ribose?

2. 1. 1. 3. 1. 4. 2

What is the effect of the space environment on the breakdown of deoxyribose?

2. 1. 1. 3. 2. 1

What is the effect of the space environment on glycogenic processes?

2. 1. 1. 3. 2. 2

What is the effect of the space environment on amino acid pools?

2. 1. 1. 3. 2. 3

What is the effect of the space environment on ketogenic processes?

2. 1. 1. 3. 3. 1. 1

What is the effect of the space environment on beta-oxidation of fatty acids?

2. 1. 1. 3. 3. 1. 2

What is the effect of the space environment on omega-oxidation of fatty acids?

2. 1. 1. 3. 3. 2

What is the effect of the space environment on the catabolism of triglycerides?

2. 1. 1. 3. 4. 1. 1

What is the effect of the space environment on carbohydrate catabolism through the pentose phosphate shunt?

2. 1. 1. 3. 4. 1. 2

What is the effect of the space environment on carbohydrate catabolism through the TCA Cycle?

2.1.1.3.4.2.1

What is the effect of the space environment on carbohydrate catabolism through the glycolytic mechanisms?

2.1.1.3.4.2.2

What is the effect of the space environment on carbohydrate catabolism through the nonglycolytic mechanisms?

2.1.2.1.1.1.1

What is the effect of the space environment on the reaction mediated by the enzyme, pyruvic oxidase?

2.1.2.1.1.1.2

What is the effect of the space environment on the reaction mediated by the isocitric enzyme?

2.1.2.1.1.1.3

What is the effect of the space environment on the reaction mediated by the enzyme, alpha ketoglutarate oxidase?

2.1.2.1.1.1.4

What is the effect of the space environment on the reaction mediated by the enzyme, succinyl thiokinase?

2.1.2.1.1.1.5

What is the effect of the space environment on the reaction mediated by the enzyme, succinic dehydrogenase?

2.1.2.1.1.1.6

What is the effect of the space environment on the reaction mediated by the enzyme, malic dehydrogenase?

2.1.2.1.1.2.1

What is the effect of the space environment on the formation of ATP at the NAD/FAD crossover point?

2.1.2.1.1.2.2

What is the effect of the space environment on the formation of ATP at the FAD/cytochrome C crossover point?

2.1.2.1.1.2.3

What is the effect of the space environment on the formation of ATP at the cytochrome C/cytochrome oxidase crossover point?

2.1.2.1.1.3.1

What is the effect of the space environment on the reaction mediated by the enzyme, glucose-6-phosphate dehydrogenase?

2.1.2.1.1.3.2

What is the effect of the space environment on the reaction mediated by the enzyme, 6-phospho gluconic acid dehydrogenase?

2.1.2.1.1.4.1

What is the effect of the space environment on the reaction mediated by the enzyme, acyl dehydrogenase?

2.1.2.1.1.4.2

What is the effect of the space environment on the reaction mediated by the enzyme, hydroxyacyl dehydrogenase?

2.1.2.1.1.5.1

What is the effect of the space environment on the reaction mediated by glutamic acid dehydrogenase?

2.1.2.1.1.5.2

What is the effect of the space environment on the reaction mediated by D-amino acid oxidase?

2.1.2.1.1.6.1

What is the effect of the space environment on the reaction mediated by the transaminases?

2.1.2.1.2.1.1

What is the effect of the space environment on the glycolitic reaction mediated by the enzyme, phosphoglyceraldehyde dehydrogenase?

2.1.2.1.2.1.2

What is the effect of the space environment on the glycolitic reaction mediated by the enzyme, phosphoglyceryl kinase?

2.1.2.1.2.1.3

What is the effect of the space environment on the glycolitic reaction mediated by the enzyme, pyruvic oxidase?

2.1.2.1.2.2.1

What is the effect of the space environment on the enzyme, nitrate reductase?

2.1.2.1.2.2.2

What is the effect of the space environment on the enzyme sulfate reductase?

2.1.2.2.1.1

What is the effect of the space environment on the reaction mediated by the enzyme, transhydrogenase (ferridoxin/NAD(P) reductase)?

- 2.1.4.2.1.1  
What is the effect of the space environment on the frequency of lethal mutations?
- 2.1.4.2.1.2  
What is the effect of the space environment on the frequency of conditional-lethal mutations?
- 2.1.4.2.1.3  
What is the effect of the space environment on frequency of nonlethal mutations?
- 2.1.4.2.2.3.1  
What is the effect of the space environment on genetic information exchange through the process of transduction?
- 2.1.4.2.2.3.2  
What is the effect of the space environment on genetic information exchange through the process of transformation?
- 2.1.5.3.1.1.1.1  
What is the effect of the space environment on physical stability?
- 2.1.5.3.1.1.1.2  
What is the effect of the space environment on rate of aerosol dissemination?
- 2.1.5.3.1.1.1.3  
What is the effect of the space environment on longevity of aerosols of different-sized particles?
- 2.1.5.3.1.1.1.4  
What is the effect of the space environment on viability of microbes in aerosols?
- 2.1.5.3.1.1.2.1  
What is the effect of the space environment on aerosol pattern of penetration into respiratory tract?
- 2.1.5.3.1.1.2.2  
What is the effect of the space environment on lodgement of microbes in respiratory tract?
- 2.1.5.3.1.1.2.3.1  
What is the effect of the space environment on disease transmission for different numbers of animals per chamber?
- 2.1.5.3.1.1.2.3.2  
What is the effect of the space environment on state of susceptibility or resistance?

2.1.5.3.1.1.2.3.3

What is the effect of the space environment on disease transmission for different levels of confirmed space per animal?

2.1.5.3.1.1.2.3.4

What is the effect of the space environment on number of microbes released by infected animal?

2.1.5.3.1.1.2.3.5

What is the effect of the space environment on type of aerosol produced?

2.1.5.3.1.1.2.4

What is the effect of the space environment on course of infection?

2.1.5.3.2.1.1

What is the effect of the space environment on quantitative alterations in normal gastrointestinal flora?

2.1.5.3.2.1.2

What is the effect of the space environment on qualitative alterations in normal gastrointestinal flora?

2.1.5.3.2.2

What is the effect of the space environment on repopulation of gastrointestinal flora after chemotherapy?

2.1.5.3.3.1.1

What is the effect of the space environment on vaccines?

2.1.5.3.3.1.2

What is the effect of the space environment on other antigens?

2.1.5.3.3.7.1

What is the effect of the space environment on microbial shock on return to Earth?

2.1.5.3.3.8.3

What is the effect of the space environment on lysozyme concentration in secretions and blood?

**EARTH ORBITAL EXPERIMENT PROGRAM  
AND REQUIREMENTS STUDY**

**SPACE BIOLOGY**

**RESEARCH CLUSTER-2-P/T-3**

**ADVANCED INVESTIGATIONS OF BIOLOGICAL PROCESSES,  
USING UNICELLULAR SPECIMENS (PROTISTS AND TISSUE CULTURES)**

*C-2-95*

Critical Issues Addressed by Research Cluster

2-P/T-3

ADVANCED INVESTIGATIONS OF BIOLOGICAL  
PROCESSES, USING UNICELLULAR SPECIMENS  
(PROTISTS AND TISSUE CULTURES)

2.1.1.1.1.1.4

What is the effect of the space environment on the biosynthesis of glycogen?

2.1.1.1.1.3.1

What is the effect of the space environment on the biosynthesis of acetyl coenzyme-A?

2.1.1.1.2.1.2

What is the effect of the space environment on the biosynthesis of cellulose?

2.1.1.1.2.1.3

What is the effect of the space environment on the biosynthesis of xylan?

2.1.1.1.2.1.4

What is the effect of the space environment on the biosynthesis of arabinose?

2.1.1.1.2.1.5

What is the effect of the space environment on the biosynthesis of mannose?

2.1.1.1.2.2.2.1

What is the effect of the space environment on the anabolism of sodium?

2.1.1.1.2.2.2.2

What is the effect of the space environment on the anabolism of potassium?

2.1.1.1.2.2.2.3

What is the effect of the space environment on the anabolism of chloride?

2.1.1.1.3.2.1.2

What is the effect of the space environment on the biosynthesis of DNA?

2.1.1.1.3.2.1.3.1

What is the effect of the space environment on the biosynthesis of messenger RNA?

- 2. 1. 1. 1. 3. 2. 1. 3. 2  
What is the effect of the space environment on the biosynthesis of transfer RNA ?
- 2. 1. 1. 1. 3. 2. 1. 3. 3  
What is the effect of the space environment on the biosynthesis of ribosomal RNA ?
- 2. 1. 1. 1. 3. 2. 1. 3. 4  
What is the effect of the space environment on the biosynthesis of other RNAs ?
- 2. 1. 1. 1. 3. 3. 1  
What is the effect of the space environment on the biosynthesis of coenzyme-A ?
- 2. 1. 1. 1. 3. 3. 2  
What is the effect of the space environment on the biosynthesis of flavins ?
- 2. 1. 1. 1. 3. 3. 3  
What is the effect of the space environment on the biosynthesis of biotin ?
- 2. 1. 1. 1. 3. 3. 4  
What is the effect of the space environment on the biosynthesis of nicotinic acid ?
- 2. 1. 1. 1. 3. 3. 5  
What is the effect of the space environment on the biosynthesis of folic acid ?
- 2. 1. 1. 1. 3. 3. 6  
What is the effect of the space environment on the biosynthesis of cobamide coenzyme ?
- 2. 1. 1. 1. 3. 3. 7  
What is the effect of the space environment on the biosynthesis of thiamine cocarboxylase ?
- 2. 1. 1. 1. 3. 3. 8  
What is the effect of the space environment on the biosynthesis of other enzyme cofactors ?
- 2. 1. 1. 2. 2. 1  
What is the effect of the space environment on the genetic processes resulting in positive feedback ?
- 2. 1. 1. 2. 2. 2  
What is the effect of the space environment on the genetic processes resulting in negative feedback ?



2. 1. 1. 3. 1. 1. 1

What is the effect of the space environment on the breakdown of ATP?

2. 1. 1. 3. 1. 1. 2

What is the effect of the space environment on the breakdown of UTP?

2. 1. 1. 3. 1. 1. 3

What is the effect of the space environment on the breakdown of ITP?

2. 1. 1. 3. 1. 1. 4

What is the effect of the space environment on the breakdown of GTP?

2. 1. 1. 3. 1. 2. 1

What is the effect of the space environment on the breakdown of adenosine?

2. 1. 1. 3. 1. 2. 2

What is the effect of the space environment on the breakdown of cytidine?

2. 1. 1. 3. 1. 2. 3

What is the effect of the space environment on the breakdown of inosine?

2. 1. 1. 3. 1. 2. 4

What is the effect of the space environment on the breakdown of guanosine?

2. 1. 1. 3. 1. 3. 1. 1

What is the effect of the space environment on the breakdown of adenine?

2. 1. 1. 3. 1. 3. 1. 2

What is the effect of the space environment on the breakdown of hypoxanthine?

2. 1. 1. 3. 1. 3. 1. 3

What is the effect of the space environment on the breakdown of xanthine?

2. 1. 1. 3. 1. 3. 1. 4

What is the effect of the space environment on the breakdown of guanine?

2. 1. 1. 3. 1. 3. 2. 1

What is the effect of the space environment on the breakdown of uracile?

- 2. 1. 1. 3. 1. 3. 2. 2  
What is the effect of the space environment on the breakdown of cytosine?
- 2. 1. 1. 3. 1. 3. 2. 3  
What is the effect of the space environment on the breakdown of thymine?
- 2. 1. 1. 3. 1. 4. 1  
What is the effect of the space environment on the breakdown of ribose?
- 2. 1. 1. 3. 1. 4. 2  
What is the effect of the space environment on the breakdown of deoxyribose?
- 2. 1. 1. 3. 2. 1  
What is the effect of the space environment on the glycogenic processes?
- 2. 1. 1. 3. 2. 2  
What is the effect of the space environment on amino acid pools?
- 2. 1. 1. 3. 2. 3  
What is the effect of the space environment on ketogenic processes?
- 2. 1. 1. 3. 3. 1. 1  
What is the effect of the space environment on beta-oxidation of fatty acids?
- 2. 1. 1. 3. 3. 2  
What is the effect of the space environment on the catabolism of triglycerides?
- 2. 1. 1. 3. 4. 1. 1  
What is the effect of the space environment on carbohydrate catabolism through the pentose phosphate shunt?
- 2. 1. 1. 3. 4. 1. 2  
What is the effect of the space environment on carbohydrate catabolism through the TCA cycle?
- 2. 1. 1. 3. 4. 2. 1  
What is the effect of the space environment on carbohydrate catabolism glycolytic mechanisms?
- 2. 1. 1. 3. 4. 2. 2  
What is the effect of the space environment on carbohydrate catabolism nonglycolytic mechanisms?

- 2.1.2.1.1.1.1  
What is the effect of the space environment on the reaction mediated by the enzyme, pyruvic oxidase?
- 2.1.2.1.1.1.2  
What is the effect of the space environment on the reaction mediated by the isocitric enzyme?
- 2.1.2.1.1.1.3  
What is the effect of the space environment on the reaction mediated by the enzyme, alpha ketoglutarate oxidase?
- 2.1.2.1.1.1.4  
What is the effect of the space environment on the reaction mediated by the enzyme, succinyl thiokinase?
- 2.1.2.1.1.1.5  
What is the effect of the space environment on the reaction mediated by the enzyme, succinic dehydrogenase?
- 2.1.2.1.1.1.6  
What is the effect of the space environment on the reaction mediated by the enzyme, malic dehydrogenase?
- 2.1.2.1.1.2.1  
What is the effect of the space environment on the formation of ATP at the NAD/FAD crossover point?
- 2.1.2.1.1.2.2  
What is the effect of the space environment on the formation of ATP at the FAD/cytochrome C crossover point?
- 2.1.2.1.1.2.3  
What is the effect of the space environment on the formation of ATP at the Cytochrome C/cytochrome oxidase crossover point?
- 2.1.2.1.1.3.1  
What is the effect of the space environment on the reactions mediated by the enzyme, glucose-6-phosphate dehydrogenase?
- 2.1.2.1.1.3.2  
What is the effect of the space environment on the reactions mediated by the enzyme, 6-phospho gluconic acide dehydrogenase?
- 2.1.2.1.1.4.1  
What is the effect of the space environment on the reactions mediated by the enzyme, acyl dehydrogenase?

2.1.2.1.1.4.2

What is the effect of the space environment on the reactions mediated by the enzyme, hydroxyacyl dehydrogenase?

2.1.2.1.1.5.1

What is the effect of the space environment on the reactions mediated by glutamic acid dehydrogenase?

2.1.2.1.1.6.1

What is the effect of the space environment on the reactions mediated by the transaminases?

2.1.2.1.2.1.1

What is the effect of the space environment on the glycolitic reaction mediated by the enzyme, phosphoglyceraldehyde dehydrogenase?

2.1.2.1.2.1.2

What is the effect of the space environment on the glycolitic reaction mediated by the enzyme, phosphoglyceryl kinase?

2.1.2.1.2.1.3

What is the effect of the space environment on the glycolitic reaction mediated by the enzyme, pyruvic oxidase?

2.1.2.1.2.2.1

What is the effect of the space environment on the enzyme, nitrate reductase?

2.1.2.1.2.2.2

What is the effect of the space environment on the enzyme, sulfate reductase?

2.1.2.2.1.1

What is the effect of the space environment on the reaction mediated by the enzyme, transhydrogenase (ferridoxin/NAD(P) reductase)?

2.1.2.2.1.2

What is the effect of the space environment on the reaction mediated by chlorophyll?

2.1.2.2.2.1

What is the effect of the space environment on the oxidation of  $\text{Fe}^{++}$  to  $\text{Fe}_2\text{O}_3$ ?

2.1.2.2.2.2

What is the effect of the space environment on the oxidation of thiosulfate to sulfate?

2.1.3.1.7

What is the effect of the space environment on any existing correlations between the tropic responses and metabolic or energetic reactions?

2.1.4.2.1.1

What is the effect of the space environment on the frequency of lethal mutations?

2.1.4.2.1.2

What is the effect of the space environment on the frequency of conditional-lethal mutations?

2.1.4.2.1.3

What is the effect of the space environment on the frequency of nonlethal mutations?

2.1.4.2.2.3.1

What is the effect of the space environment on genetics information exchange through the processes of transduction?

2.1.4.2.2.3.2

What is the effect of the space environment on the genetics information exchange through the processes of transformation?

2.1.4.2.3.1.1

What is the effect of the space environment on DNA, as manifested by induction?

2.1.4.2.3.1.2

What is the effect of the space environment on DNA, as manifested by repression?

2.1.4.2.3.2.1

What is the effect of the space environment on RNA, and do the effects arise from enzyme synthesis?

2.1.4.2.3.2.2

What is the effect of the space environment on RNA, and do the effects arise from nucleotide synthesis?

2.1.5.3.2.1.1.3

What is the effect of the space environment on selective factors for virulent agents?

2.1.5.3.2.1.1.4

What is the effect of the space environment on protective functions?

2.1.5.3.3.6

What is the effect of the space environment on  
macrophage antigen processing?

2.1.5.3.3.7.2

What is the effect of space environment on long-term  
inflight effect on susceptibility to infection?

2.1.5.3.3.8.1

What is the effect of space environment on muco-  
ciliary function?

2.1.5.3.3.8.2

What is the effect of space environment on phagocytic  
clearance?

2.1.5.3.3.8.4

What is the effect of space environment on peristalsis?

2.1.5.3.4.1

What is the effect of space environment on factors  
that alter host defenses?

2.1.5.3.4.2

What is the effect of space environment on factors  
that activate latent infections?

TABLE 1. LEGEND OF CODES USED IN CREW ACTIVITY MATRICES

Table 1 is an explanation of the codes used in the following matrices. The matrices summarize the inflight crew tasks required to conduct and support the research identified in the synopsis.

TYPE OF ACTIVITY

- |   |   |
|---|---|
| 0 - Not covered below                   | 5 - Conduct of experiment   |
| 1 - Experimental subject                | 6 - Evaluate intermediate results   |
| 2 - Spacecraft operations               | 7 - Direct observation of phenomena                                       |
| 3 - Preexperiment equipment preparation | 8 - Data handling   |
| 4 - Maintenance of equipment            | 9 - Communications; initiate and receive transmissions (telemetry, voice) |

CREW SKILL

- |                               |                      |
|-------------------------------|----------------------|
| 0 - No special skill required | 12 - Meteorology     |
| 1 - Medicine                  | 13 - Geography       |
| 2 - Biology                   | 14 - Cartography     |
| 3 - Physiology                | 15 - Hydrology       |
| 4 - Psychology                | 16 - Navigation      |
| 5 - Engineering               | 17 - Communications  |
| 6 - Astronomy                 | 18 - Radiology       |
| 7 - Physics                   | 19 - Instrumentation |
| 8 - Oceanography              | 20 - Photography     |
| 9 - Forestry                  | 21 - Astronaut       |
| 10 - Agriculture              | 22 - Other           |
| 11 - Geology                  |                      |

Each code includes the first one or two digits describing the discipline and a second code letter describing level of skill: A for highest skill level (requires professional training with degree or advanced degree in discipline such as M. D.); B for semiprofessional, the traditional technician level requiring several years of training; C for technician level which requires some special training.

C-2-102-a

\*3a = Post experiment equipment storage and cleanup.

CREW ACTIVITY MATRIX (Page 1 of 2)

RESEARCH CLUSTER NO.	TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY	REMARKS	EXCLU-SIVE	CREW SKILL	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START	DURA-TION	TASK CONCURRENCY
2-P/T-1 (a)	Frog egg morphogenesis											
(p. 1 of 2)	1. Observe temperature display on frog egg module	frog egg module	4		X	0	daily	30 sec	1	'74	90-100 days	
	2. Disconnect and package frog egg module for return	frog egg module return package	8		X	2c	once only	1 hr	1	"	--	
(b)	Bacterial growth											
	1. Remove cultures from module	bacterial module	3a*		X	2c	"	10 min	1	"	--	
	2. Place cultures in autoclave and sterilize	autoclave and cultures	3a	crewman time = 15 min		2c	"	1 hr	1	"	--	
	3. Remove cultures from autoclave and discard	disposal	3a		X	2c	"	15 min	1	"	--	
(c)	Neurospora Morphology											
	1. Observe incubator temperature	thermometer on incubator	4		X	0	daily	30 sec	1	'77	30 days	
	2. Remove cultures from incubator	incubator and cultures	3		X	2c	daily	5 min	1	'77	"	
	3. Measure colony size	metric ruler	5		X	2c	daily	10 min	1	'77	"	
	4. Observe and photograph growth rings	camera	5		X	2c	daily	20 min	1	'77	"	
	5. Observe conidial morphology and density	none	5		X	2c	daily	10 min	1	'77	"	
	6. Record observations	data sheets	8		X	2c	daily	15 min	1	'77	"	
	7. Return cultures to incubator	incubator	3a		X	2c	daily	5 min	1	'77	"	
(d)	Bacterial genetics											
	1. Calibrate optical densitometer	optical densitometer	3		X	2c	daily	20 min	1	'77	5 days	
	2. Remove culture from incubator	incubator	3		X	2c	daily	5 min	1	'77	"	
	3. Sterilely transfer a portion of culture to cuvette	optical densito- meter, cuvettes, pipettes	5		X	2c	daily	15 min	1	'77	"	
	4. Read optical density scale	optical densitometer	5		X	2c	daily	15 min	1	'77	"	
	5. Record readings	data sheets	8		X	2c	daily	5 min	1	'77	"	
	6. Sterilize and dispose of samples	autoclave	3a			2c	daily	1.2 hrs	1	'77	"	
(Mutant frequency)	7. Prepare selective media	bacteriology laboratory	5		X	2c	once/wk	1 hr	1	'77	5 wks	
	8. Prepare cultures and dilution blank	"	5		X	2c	"	1 hr	1	'77	"	
	9. Incubate cultures	incubator	5			2c	"	24 hrs	(1)	'77	"	
	10. Count colonies of mutants on plates	culture plates	5		X	2c	"	1 hr	1	'77	"	



RESEARCH CLUSTER NO.	TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY	REMARKS	EXCLUSIVE	CREW SKILL	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START	DURATION	TASK CONCURRENCY
2-P/T-1 (p. 2 of 2)												
	11. Sterilize and dispose of samples	autoclave	3a			2c	once/wk	1.2 hrs	1	'77	5 wks	
	12. Record data	data sheets	8		X	2c	"	10 min	1	'77	"	
(Transformation)	13. Prepare and incubate cultures for transformation	bacteriological lab and incubator	5	crewman time 2 hrs/day		2c	"	26 hrs	1	'77	6 wks	
	14. Extract DNA	refrigerated centrifuge	5		X	2b	"	1 hr	1	'77	"	
	15. React DNA with competent bacteria	bacteriology laboratory	5	crewman time 10 min/week		2b	"	1 hr	1	'77	"	
	16. Prepare cultures of recombinant forms on media plates	"	5		X	2b	"	2 hrs	1	'77	"	
	17. Incubate plates	incubator	5	crewman time 10 min/week		2c	"	24 hrs	1	'77	"	
	18. Inspect for recombinant colonies	culture plates	5		X	2b	"	1 hr	1	'77	"	
	19. Record data	data sheets	8		X	2b	"	15 min	1	'77	"	
	20. Sterilize and dispose of specimens	autoclave	3a	crewman time 15 min/week		2c	"	1.2 hrs	1	'77	"	
(Conjugation)	21. Grow colonies of bacteria appropriate for conjugation (one with chromosome marker)	incubator	5			2c	---	---	1	'77	"	
	22. Mix and allow for conjugation	culture tubes	5	crewman time 10 min/day		2b	daily	30 min	1	'77	25 days	
	23. Shake loose and plate	culture plates	5		X	2b	"	1.5 hrs	1	'77	"	
	24. Incubate	incubator	5	crewman time 10 min/day		2c	"	24 hrs	1	'77	"	
	25. Inspect colonies for transfer of chromosome markers		5		X	2b	"	?	1	'77	75 days	
	26. Record data	data sheets	8		X	2b	"	15 min	1	'77	"	
	27. Sterilize and dispose of samples	autoclave	3a	crewman time 15 min/day		2c	"	1.2 hrs	1	'77	"	
(e)	Tissue culture growth and organization											
	1. Maintenance of incubating tissue culture	incubator	4		X	2c	"	10 min	1	'77	10 days	
	2. Examine cultures under microscope	microscope	5		X	2b	"	10 min	1	'77	"	
	3. Record data	data sheets	8		X	2b	"	5 min	1	'77	"	

CREW ACTIVITY MATRIX (Page 1 of 4)

RESEARCH CLUSTER NO.	TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY	REMARKS	EXCLUSIVE	CREW SKILL	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START	DURATION	TASK CONCURRENCY
2-P/T-2 (a)	Aerosol Stability											
(p. 1 of 4)	1. Set up aerosolizer and air sampler	aerosolizer and air sampler	3		X	2c	weekly	15 min.	1		10 wks.	
	2. Produce aerosols	" "	5	crewman time = 10 min/week		2c	weekly	1 hr.	1		"	
	3. Record particle count	data sheet	8		X	2c	weekly	10 min.	1		"	
(b)	Aerosol Dissemination Rate											
	1. Set up aerosolizer	aerosolizer	3		X	2c	weekly	10 min.	1		"	
	Set up air samplers at various distances from aerosolizer	air samples	3		X	2c	weekly	10 min.	1		"	
	3. Produce aerosols	aerosolizer	5	crewman time = 10 min/week		2c	weekly	1 hr.	1		"	
	4. Record particle count at each sampler	air samples	5		X	2c	weekly	included in above	1		"	
	5. Record data	data sheets	8		X	2c	weekly	15 min.	1		"	
(c)	Particle size vs aerosol stability											
	1. Set up aerosolizer and air sampler	aerosolizer and air samplers	3		X	2c	once/day	15 min.	1		24 days	
	2. Produce aerosol of specified particle size	" "	5	crewman time = 10 min/day		2c	once/day	1 hr.	1		—	
	3. Record particle count at sampler	data sheets	5 & 8		X	2c	once/day	5 min.	1		3 days	
	4. Repeat 2 and 3 for additional aerosol particle sizes	aerosolizer and air sampler	5	crewman time = 10 min/day		2c	once/day	1 hr.	1		21 days	
	5. Store aerosolizer and air sampler	" "	5	crewman time = 10 min/day		2c	daily	10 min.	1		24 days	
(d)	Microbial Viability in Aerosols											
	1. Set up aerosolizer	aerosolizer	3		X	2c	once only	10 min.	1		—	
	2. Set up Anderson air sampler	Anderson air sampler	3		X	2b	20/day	5 min.	1		—	
	3. Produce aerosol	aerosolizer	5	crewman time = 10 min/day		2c	daily	1 hr.	1		3 days	
	4. Place Anderson filter on culture plate	culture plates	5		X	2b	20/day	5 min.	1		"	
	5. Incubate	incubator	5	crewman time = 20 min/day		2c	20 plates per day	24hrs.	1		"	
	6. Count colonies of viable organisms	culture plates	5 & 8		X	2b	once only	5 hrs.	1		—	
	7. Sterilize and discard cultures	autoclave	3a	crewman time = 15 min		2c	once only	75 min.	1		—	
	8. Store aerosolizer and air sampler	aerosolizer and air sampler	3a		X	2c	once only	10 min.	1		—	
(e)	Aerosol penetration into respiratory tract											
	1. Set up aerosolizer	aerosolizer	3		X	2c	daily	10 min.	1		3 days	

RESEARCH CLUSTER NO.	TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY	REMARKS	EXCLUSIVE	CREW SKILL	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START	DURATION	TASK CONCURRENCY
2-P/T-2 (p. 2 of 4)												
	2. Expose mice to aerosol	mice	5	crewman time 30 min/day		2c	daily	5 hrs	1		3 days	
	3. Sacrifice animals	surgical equipment	5		X	2b	daily	1 hr	1		"	
	4. Inspect respiratory tracts for presence of particles	"	5		X	2c	daily	2 hrs	1		"	
	5. Record data	data sheets	8		X	2b	daily	15 min	1		"	
	6. Store aerosolizer	aerosolizer	3a		X	2c	daily	5 min	1		"	
	7. Dispose of animals and tissues	incinerator	3a	crewman time 20 min/day		2c	daily	1 hr.	1		"	
(f)	Susceptibility of mice to aerosol borne infections											
	Set up aerosolizer for production of aerosol of infectious organisms	aerosolizer	3		X	2b	once/mo.	15 min.	1		3 mos.	
	2. Expose mice to aerosols	mice	5	crewman time 15 min/month		2b	once/mo.	1 hr.	1		"	
	3. Store aerosolizer and return mice to cage		3a		X	2c	once/mo.	20 min.	1		"	
	4. Sterilize chamber	chemical spray	3a	crewman time 20 min/month		2c	once/mo.	1 hr.	1		"	
	5. Observe health of mice	mice storage cages	5 & 6		X	2b	daily	15 min.	1		"	
	6. Sacrifice and dispose of animals	toxic chamber	3a		X	2c	once only	2 hrs.	1		—	
	7. Record data	data sheets	8		X	2b	daily	10 min	1		3 mos.	
(g)	Floral Alterations of Crew											
	1. Prepare media, plates, data sheets, etc.	bacteriological laboratory	3		X	2b	monthly	4 hrs.	2		12 mos.	
	2. Obtain samples from crew	swabs	5	6 crewmen serve as subj. 10/min/crew./wk	X	2b	weekly	30 min.	2		1 yr.	
	3. Culture samples	culture plates	5		X	2b	weekly	2 hrs	1		"	
	4. Incubate	incubator	5	crewman time 10 min/wk		2c	weekly	1 hr.	1		"	
	5. Obtain colony counts	colony counter	5		X	2b	weekly	2 hrs.	2		"	
	6. Record data	data sheets	8		X	2b	weekly	20 min.	1		"	
	7. Isolate colonies on separate plates	culture plates	5		X	2b	once/ 2 wks.	3 hrs.	2		"	
	8. Incubate	incubator	5	crewman time 10 min/2 weeks		2c	once/ 2 wks.	1 hr.	1		"	
	9. Identify colonies	colony scanner and computer	5		X	2b	once/ 2 wks.	3 hrs.	1		"	
	10. Record data	data sheets	8		X	2b	once/ 2 wks.	20 min.	1		"	
	11. Sterilize and dispose of cultures	autoclave	3a	crewman time 30 min/month		2c	monthly	90 min.	1		"	

RESEARCH CLUSTER NO.	TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY	REMARKS	EXCLU- SIVE	CREW SKILL	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START	DURA- TION	TASK CONCURRENCY
2-P/T-2 (p. 3 of 4)												
(h)	Repopulation of Gut Flora after Chemotherapy											
	1. Collect fecal samples	waste management system	5	collected by each of 6 subjects	X	0	once/2 weeks	15 min. per man	6		1 yr	
	2. Culture samples	culture plates	5		X	2b	"	1 hr.	1		"	
	3. Incubate	incubator	5	crewman time 10 min/2 wks		2c	"	24 hrs.	1		"	
	4. Obtain colony counts	colony counter	5		X	2b	"	1 hr.	1		"	
	5. Record data	data sheets	8		X	2b	"	15 min	1		"	
	6. Isolate colonies on separate plates	culture plates	5		X	2b	"	3 hrs	2		"	
	7. Incubate	incubator	5	crewman time 10 min/2 wks		2c	"	24 hrs	1		"	
	8. Identify colonies	colony scanner and computer	5		X	2b	"	3 hrs	1		"	
	9. Record data	data sheets	8		X	2b	"	20 min	1		"	
	10. Sterilize and dispose of cultures	autoclave	3a	crewman time 30 min/month		2c	monthly once	90 min	1		"	
	11. Administer chemotherapy	---	5		X	2b	only once	15 min	1		"	
	12. Repeat tasks "1" through "10"	same as above	5 & 8			2b	once see above 2 weeks		1 & 2		"	
(i)	Immune response to antigens											
	1. Inject rats with antigen	rats and vaccine	5		X	2b	once only	1.5 hrs	2		--	
	2. Observe animals' health	---	6		X	2b	daily	15 min.	1		30 days	
	3. Obtain blood samples	syringes and needles	5		X	2b	daily	1 hr.	2		"	
	4. Observe for agglutination reactions	bacteriological laboratory	5		X	2b	daily	15 min	2		"	
	5. Record data	data sheets	8		X	2b	daily	15 min	1		"	
	6. Dispose of samples	incinerator	3a		X	2c	once only	30 min	1		--	
(j)	Lysozyme in secretions and blood											
	1. Prepare tubes of lysozyme susceptible cells	bacteriological laboratory	3		X	2b	weekly	1 hr.	1		--	
	2. Obtain blood and secretion samples and add to tubes	syringes and needles	5	samples from each of 6 crewmen 10 min/crewman/week	X	2b	weekly	1 hr.	1		30 wks	
	3. Calibrate optical densitometer	optical densitometer	3 & 4		X	2c	weekly	20 min	1		"	
	4. Read densitometer and compare with calibration curve	"	5		X	2b	weekly	90 min	1		"	

C-2-108

RESEARCH CLUSTER  
NO. 2-P/T-3

C-2-109

EARTH ORBITAL EXPERIMENT PROGRAM  
AND REQUIREMENTS STUDY

SPACE BIOLOGY

RESEARCH CLUSTER-2-PL-1  
PRELIMINARY INVESTIGATIONS OF BIOLOGICAL  
PROCESSES, USING PLANTS

*C-2-110*

RESEARCH CLUSTER  
SYNOPSIS—SPACE BIOLOGY

2-PL-1

Preliminary Investigations of Biological Processes, Using Plants

**1. Research Objectives**

Dividing the Space Biology Research Program into specimen-oriented research clusters permits a large number of specific research objectives to be undertaken within a particular experiment group. The present research cluster, which is oriented toward an investigation of biological processes in plants, includes experiments on growth, metabolism, respiration, energetics, tropistic responses, rhythmic movements, development, and genetic processes. As a consequence of this broad spectrum of research activities, the research cluster is more properly identified with Broad Objectives rather than with Supporting Specific Objectives. The NASA-defined Scientific and Technological Objectives in Space Biology to which experiments on plants may be expected to contribute are:

1. To understand the role of gravity in life processes and the capability of living organisms to adapt to gravitational changes.
2. To understand the role of time in biology, including the effects of time-varying environmental parameters on biological rhythms and aging.

The critical issues related to the objectives of this research cluster are most easily referable to the three-dimensional matrix from which the various issues were derived (Chart 2-1, Appendix A). The taxonomy axis is, by nature of this research division, restricted to plants. The environment axis will be restricted through experimental controls to the effects of zero-g. On the axis dealing with life processes, the categories concerned with metabolism, energetics, response to stimuli, and reproduction are legitimate candidates for research. Many of the physiological areas, such as the nervous system and most organ systems, are limited to animal research; and the behavioral areas are not at all applicable to plant research.

The specific experiment objective associated with this research cluster is the investigation of the physiological, gross morphological, and histochemical changes elicited in plants as a result of the absence of gravitational stimulation.

**2. Background and Current Status**

Ground-based research with the clinostat indicated that developmental, physiological, and tropistic changes occur when plants are deprived of their gravitational orientation. In actual spaceflight, the morphological response of wheat seedlings and young leafy



pepper plants to weightlessness were determined through experiments performed in Biosatellite II. An indication of physiological aberrations resulting from orbital flight has also been observed in the wheat-seedling experiment.

The two plant experiments included in Biosatellite were designed to survey the effects of spaceflight factors. Now that positive results have been demonstrated, which indicate that the growth processes in space are different from those on Earth, it is necessary to perform additional experiments to fully understand the manner and mechanisms by which plants are affected by weightlessness. Additional experimentation is also required to determine the extent to which clinostat experiments can be used to simulate weightlessness.

### 3. Description of Research

Experiments investigating the biological processes of plants in the space environment potentially include a large number and broad variety of observations from the simple observation and preservation of cucumber plants grown from seeds in space to the extremely sophisticated measurements on metabolic pathways in plants by the use of radio-isotopic tags.

The sequencing of experiments is based on both experimental design and expediency. The common scientific approach of initial general observations, followed by more complete examination of those aspects showing alterations, and concluding in detailed studies of mechanisms is quite appropriate to space biology. Additionally, the recognition of the limitations of crew size, available time, and specialized skills in early spaceflights leads to the design of experiments which, at first, require minimal crew involvement; next, moderate involvement; and later, extensive crew involvement. These two approaches are quite compatible and are readily combined in program definition.

The preliminary phase (Phase I), Research Cluster 2-PL-1, of the plant experiment program will utilize only man's ability to maintain the biological specimens and make meaningful observations. Included in this phase are experiments recommended for inclusion in the Skylab B and Early Space Station programs. These experiments involve the study of Arabidopsis plant growth and development in weightlessness, the role of gravity in cucumber lignification, and the verification of Skylab A experiment S-061, potato respiration rhythms. Measurements and observations will include time-lapse photography of plant growth, harvesting and planting of seeds for the observation of subsequent generations, preservation of specimens at specified stages of development, and the measurement of O<sub>2</sub> and CO<sub>2</sub> concentrations within the potato module. Crew activities will be limited to the periodic preservation and storage of plants, the harvesting and planting of seeds, and the preparation of all specimens for return to Earth. These experiments are designated 3-104, 3-105, and 3-213 and are

detailed in Phase II of A Requirements Study for a Biotechnology Laboratory for Manned Earth-Orbiting Missions, NASA CR 111794 and summarized in Appendix H of this report.

Experiments conducted during the intermediate phase (Phase II), Research Cluster 2-PL-2, characterized by research on previously observed changes and increased experiments participation, are exemplified by the experiments recommended for the Mid Space Station in the above-referenced biotechnology laboratory study. These experiments include the effects of weightlessness on marigold geotropism, metabolism, development and cellular structure and organization; on wheat seedling photo-sensitivity, geosensitivity, metabolism, morphogenesis, cell structure and organization, and host-parasite relationships on the morphogenesis and metabolism of Pteris; and on bean-seedling metabolism, morphogenesis, and cellular structure and organization, designated 3-225, 3-226, 3-233, and 3-234. A significant increase in crew activity is associated with these experiments, including the microdissection, observation, and preservation of the specimens; the preparation of specimen homogenates for metabolic studies; and the conduct of metabolic studies through the identification of products or substrate changes by means of radioisotopic tags or spectrophotometric analysis. Research during the intermediate phase (Phase II) will require laboratory specialists trained and experienced as biological scientists (technologists) who are alternately trained as astronauts. The full-time participation of two such individuals should be anticipated in this phase of the space biology program.

Experiments during the advanced phase (Phase III), Research Cluster 2-PL-3, will be directed toward the investigation of mechanisms. The techniques will be sophisticated, and extensive experiments participation will be required. Insofar as changes cannot as yet be predicted, no specific experiments can be assumed for the determination of mechanisms. Regardless of the details of each, the experiments will undoubtedly involve studies at the subcellular level, including investigation of metabolic pathways and transport mechanisms. Activities will include the isolation of enzymes, the reaction of tagged substrates with the enzyme system (the substrate being tagged with a radioactive or heavy or light isotope tracer before flight), and the determination of enzyme activity by measuring isotope disappearance from the substrate or its appearance in the products of the reaction. Such studies require advanced instrumentation, complex and precise techniques, and fully experienced investigators. It would be desirable for the principal investigator to be on board for the conduct of the experiments. In his absence, the experiments should be conducted by a highly qualified technician experienced in the field. He should be assisted by at least two experienced technologists. The duties of the team should be essentially restricted to space biology research.

#### 4. Impact on Spacecraft

The major impact of experiments conducted during the preliminary phase will be produced by the design requirements of experimental modules. The Arabidopsis module is self-contained, maintaining the plants at Earth ambient pressure, 25°C, and 75-percent relative humidity. It also provides an internal camera for photographic coverage. It weighs 70 lb, occupies 2 cu ft, and requires 20 w for 12 hr per day (light) and 10 w for 12 hr per day (dark). It outputs data from the various environmental sensors but requires a recording capability from the spacecraft system. Every 21 days, during seed harvesting and planting, the module will be decompressed and will equilibrate with the spacecraft atmosphere. The cucumber module will also be self-contained with an Earth ambient environment. It will automatically release a measured quantity of water to hydrate preplanted seeds to initiate the experiment. No photography will be required. The module weighs 80 lb, occupies 9 cu ft, and requires 70 w for 12 hr per day (light) and 10 w for 12 hr per day (dark). It will be decompressed only at the termination of the experiment when the plants are preserved and prepared for return to Earth.

Research during the intermediate phase will continue to require self-contained modules for the plants, the number of modules depending on the number of experiments selected for a specific mission. Certain laboratory facilities will also be required. A tissue-preparation laboratory will be needed, which should include a refrigerated centrifuge, a homogenizer, dialysis equipment, and an incubation facility. For the analysis of the various parameters potentially subject to change, a spectrophotometer, a mass spectrometer, a gas chromatograph, radiation detectors, and potentiometric measuring devices will be required. Much of this equipment will be common to other areas of space biology research.

Experiments conducted during the advanced phase will continue to include modules for experimental organisms although the requirements for modular self-containment will be reduced. Laboratory requirements will be increased to include facilities capable of permitting enzyme isolation, measuring cellular metabolism, and studying membrane phenomena and transport systems.

#### 5. Required Supporting Technology Development

The development, design construction, and testing of the experimental modules is the major task of required research and technology. A number of subsystems must be designed and integrated for the proper overall functioning of the module. This work is already in progress at various universities and NASA centers. Valuable design information was derived from the design of the Biosatellite II modules. Some of the laboratory equipment required for studies conducted during the intermediate phase is planned for IMBLMS, the major exception being the equipment

required for tissue preparation. These items require development, testing, and integration. Research during the advanced phase is almost totally in the area of supporting technology development. Conceptual studies must be undertaken in all cases to properly integrate the laboratories in the overall Space Station design.

Critical Issues Addressed by Research Cluster

2-PL-1

PRELIMINARY INVESTIGATIONS OF BIOLOGICAL  
PROCESSES, USING PLANTS

2.1.1.1.1.1.1

What is the effect of the space environment on the biosynthesis of starch?

2.1.1.1.1.1.2

What is the effect of the space environment on the biosynthesis of fructosans?

2.1.1.1.1.1.3

What is the effect of the space environment on the biosynthesis of mannans?

2.1.1.1.1.1.5

What is the effect of the space environment on the biosynthesis of dextran?

2.1.1.1.1.3.1

What is the effect of the space environment on the biosynthesis of acetyl coenzyme-A?

2.1.1.1.2.1.2

What is the effect of the space environment on the biosynthesis of cellulose?

2.1.1.1.2.1.3

What is the effect of the space environment on the biosynthesis of xylan?

2.1.1.1.2.1.4

What is the effect of the space environment on the biosynthesis of arabinose?

2.1.1.1.2.1.5

What is the effect of the space environment on the biosynthesis of mannose?

2.1.1.1.2.1.6

What is the effect of the space environment on the biosynthesis of lignin?

2.1.1.1.3.3.1

What is the effect of the space environment on the biosynthesis of coenzyme-A?

2.1.1.1.3.3.2

What is the effect of the space environment on the biosynthesis of flavins?

2.1.1.1.3.3.3

What is the effect of the space environment on the biosynthesis of biotin?

2.1.1.1.3.3.4

What is the effect of the space environment on the biosynthesis of nicotinic acid?

2.1.1.1.3.3.5

What is the effect of the space environment on the biosynthesis of folic acid?

2.1.1.1.3.3.6

What is the effect of the space environment on the biosynthesis of cobamide coenzyme?

2.1.1.1.3.3.7

What is the effect of the space environment on the biosynthesis of thiamine cocarboxylase?

2.1.1.1.3.3.8

What is the effect of the space environment on the biosynthesis of other enzyme cofactors?

2.1.1.2.1.1.1

What is the effect of the space environment on the metabolic control functions of auxins?

2.1.1.2.1.1.2

What is the effect of the space environment on the metabolic control functions of kinetins?

2.1.1.2.1.1.3

What is the effect of the space environment on the metabolic control functions of gibberellins?

2.1.1.3.2.1

What is the effect of the space environment on glycogenic processes?

2.1.1.3.2.2

What is the effect of the space environment on amino acid pools?

2.1.1.3.2.3

What is the effect of the space environment on ketogenic processes?

2.1.1.3.3.1.1

What is the effect of the space environment on beta-oxidation of fatty acids?

2.1.1.3.3.1.2

What is the effect of the space environment on omega-oxidation of fatty acids?

2.1.2.1.1

What is the effect of the space environment on aerobic mechanisms?

2.1.2.1.1.1.1

What is the effect of the space environment on the reaction mediated by the enzyme, pyruvic oxidase?

2.1.2.1.1.1.2

What is the effect of the space environment on the reactions mediated by the isocitric enzyme?

2.1.2.1.1.1.3

What is the effect of the space environment on the reactions mediated by the enzyme, alpha ketoglutarate oxidase?

2.1.2.1.1.1.4

What is the effect of the space environment on the reactions mediated by the enzyme, succinyl thiokinase?

2.1.2.1.1.1.5

What is the effect of the space environment on the reactions mediated by the succinic dehydrogenase?

2.1.2.1.1.1.6

What is the effect of the space environment on the reactions mediated by the enzyme, malic dehydrogenase?

- 2.1.2.1.1.3.1  
What is the effect of the space environment on the reactions mediated by the enzyme, glucose-6-phosphate dehydrogenase?
- 2.1.2.1.1.3.2  
What is the effect of the space environment on the reactions mediated by the enzyme, 6-phospho gluconic acid dehydrogenase?
- 2.1.2.1.1.4.1  
What is the effect of the space environment on the reactions mediated by the enzyme, acyl dehydrogenase?
- 2.1.2.1.1.4.2  
What is the effect of the space environment on the reactions mediated by the enzyme, hydroxyacyl dehydrogenase?
- 2.1.2.1.1.5.1  
What is the effect of the space environment on the reactions mediated by glutamic acid dehydrogenase?
- 2.1.2.1.1.6.1  
What is the effect of the space environment on the reactions mediated by the transaminases?
- 2.1.2.1.2.1.1  
What is the effect of the space environment on the glycolitic reaction mediated by the enzyme, phosphoglyceraldehyde dehydrogenase?
- 2.1.2.1.2.1.2  
What is the effect of the space environment on the glycolitic reaction mediated by the enzyme, phosphoglyceryl kinase?
- 2.1.2.1.2.1.3  
What is the effect of the space environment on the glycolitic reaction mediated by the enzyme, pyruvic oxidase?
- 2.1.2.2.1.1  
What is the effect of the space environment on the reaction mediated by the enzyme, transhydrogenase (ferridoxin/ NAD(P) reductase)?
- 2.1.3.1.1  
What is the effect of the space environment on geotropic response?
- 2.1.3.1.2  
What is the effect of the space environment on phototropic response?



2.1.3.1.3

What is the effect of the space environment on thermotropic response?

2.1.3.1.4

What is the effect of the space environment on hydrotropic response?

2.1.3.1.5

What is the effect of the space environment on chemotropic response?

2.1.3.1.6

What is the effect of the space environment on the possibility of an interaction between two or more of the tropic responses?

2.1.3.1.7

What is the effect of the space environment on any existing correlations between the tropic responses and metabolic or energetic reactions?

2.1.3.2.1.3

What is the effect of the space environment on circadian rhythms, as manifested by flower and leaf movements?

2.1.3.2.1.4

What is the effect of the space environment on circadian rhythms, as manifested by organic acid metabolism in succulents?

2.1.3.2.1.5

What is the effect of the space environment on circadian rhythms, as manifested by phototaxis?

2.1.3.2.1.6

What is the effect of the space environment on circadian rhythms, as manifested by rate of photosynthesis?

2.1.3.2.1.8

What is the effect of the space environment on circadian rhythms, as manifested by cell division?

2.1.3.2.1.9

What is the effect of the space environment on circadian rhythms, as manifested by root exudation?

2. 1. 3. 2. 3. 1

What is the effect of the space environment on semilunar rhythms, as exhibited by marine algae spore and gamete liberation?

2. 1. 3. 2. 5. 1

What is the effect of the space environment on annual rhythms resulting from photoperiodism?

2. 1. 3. 2. 5. 4

What is the effect of the space environment on annual rhythms manifested by seed germination?

2. 1. 3. 2. 5. 6

What is the effect of the space environment on annual rhythms manifested by growth rate of plants?

2. 1. 3. 2. 6. 2

What is the effect of the space environment on rhythms that are independent of environmental periodicities, as exemplified by leaf movements?

2. 1. 3. 2. 6. 3

What is the effect of the space environment on rhythms that are independent of environmental periodicities, as exemplified by protoplasmic movement in the slime mold?

2. 1. 3. 2. 6. 4

What is the effect of the space environment on rhythms that are independent of environmental periodicities, as exemplified by stomatal openings?

2. 1. 3. 2. 6. 5

What is the effect of the space environment on rhythms that are independent of environmental periodicities, as exemplified by variation of root tip electrical potential?

2. 1. 3. 2. 6. 6

What is the effect of the space environment on rhythms that are independent of environmental periodicities, as exemplified by shoot, root, and tendril growth?

2. 1. 3. 2. 6. 7

What is the effect of the space environment on rhythms that are independent of environmental periodicities, as exemplified by flowering of bamboo?

2. 1. 3. 2. 6. 8

What is the effect of the space environment on rhythms that are independent of environmental periodicities, as exemplified by glycolytic enzyme oscillations?

2.1.4.1.1.2.1

What is the effect of the space environment on plant sexual reproduction by isogametes?

2.1.4.1.1.2.2

What is the effect of the space environment on plant sexual reproduction by heterogametes?

2.1.4.1.1.2.2.1

What is the effect of the space environment on heterogametic plant reproduction, as found in antheridium?

2.1.4.1.1.2.2.2

What is the effect of the space environment on heterogametic plant reproduction, as found in oogonium?

2.1.4.2.1.1

What is the effect of the space environment on the frequency of lethal mutations?

2.1.4.2.1.2

What is the effect of the space environment on the frequency of conditional-lethal mutations?

2.1.4.2.1.3

What is the effect of the space environment on the frequency of nonlethal mutations?

2.1.4.2.1.3.1

What is the effect of the space environment on the frequency of nonlethal mutations, as manifested by structural abnormalities?

2.1.4.2.1.1.2

What is the effect of the space environment on the frequency of nonlethal mutations, as manifested by biochemical abnormalities?

2.1.4.2.1.1.3

What is the effect of the space environment on the frequency of nonlethal mutations, as manifested by chromosomal abnormalities?

2.1.5.1.2.2.3.1

What is the effect of the space environments on the response of structural support to external stress?

2.1.5.1.2.2.3.2

What is the effect of the space environment on the response of structural support to internal stress?

2.1.5.1.2.2.3.3

What is the effect of the space environment on the response of structural support to plant shape?

2.1.5.1.3.1.1

What is the effect of the space environment on the transport of organic nutrients?

2.1.5.1.3.1.2

What is the effect of the space environment on the transport of inorganic nutrients?

2.1.5.1.5.2

What is the effect of the space environment on life span?

**EARTH ORBITAL EXPERIMENT PROGRAM  
AND REQUIREMENTS STUDY**

**SPACE BIOLOGY**

**RESEARCH CLUSTER-2-PL-2  
INTERMEDIATE INVESTIGATIONS OF BIOLOGICAL  
PROCESSES, USING PLANTS**

*C-2-123*

INTERMEDIATE INVESTIGATIONS OF BIOLOGICAL  
PROCESSES, USING PLANTS

Critical Issues Addressed by Research Cluster

2-PL-2

2.1.1.1.1.1.1

What is the effect of the space environment on the biosynthesis of starch?

2.1.1.1.1.1.2

What is the effect of the space environment on the biosynthesis of fructosans?

2.1.1.1.1.1.3

What is the effect of the space environment on the biosynthesis of mannans?

2.1.1.1.1.1.5

What is the effect of the space environment on the biosynthesis of dextran?

2.1.1.1.1.3.1

What is the effect of the space environment on the biosynthesis of acetyl coenzyme-A?

2.1.1.1.2.1.2

What is the effect of the space environment on the biosynthesis of cellulose?

2.1.1.1.2.1.3

What is the effect of the space environment on the biosynthesis of xylan?

2.1.1.1.2.1.4

What is the effect of the space environment on the biosynthesis of arabinose?

2.1.1.1.2.1.5

What is the effect of the space environment on the biosynthesis of mannose?

2.1.1.1.2.1.6

What is the effect of the space environment on the biosynthesis of lignin?

2.1.1.1.2.1.7

What is the effect of the space environment on the biosynthesis of other polysaccharides?

2.1.1.1.2.2.1.1

What is the effect of the space environment on the anabolism of calcium?

2.1.1.1.2.2.2.1

What is the effect of the space environment on the anabolism of sodium?

2.1.1.1.2.2.2.2

What is the effect of the space environment on the anabolism of potassium?

2.1.1.1.2.2.2.3

What is the effect of the space environment on the anabolism of chloride?

2.1.1.1.2.2.2.4

What is the effect of the space environment on the anabolism of other nonskeletal minerals?

2.1.1.1.3.1.1.1

What is the effect of the space environment on the biosynthesis of auxins?

2.1.1.1.3.1.1.2

What is the effect of the space environment on the biosynthesis of kinetins?

2.1.1.1.3.1.1.3

What is the effect of the space environment on the biosynthesis of gibberellins?

2.1.1.1.3.2.1.1.1

What is the effect of the space environment on the biosynthesis of ATP?

2.1.1.1.3.2.1.1.2

What is the effect of the space environment on the biosynthesis of UTP?

2.1.1.1.3.2.1.1.3

What is the effect of the space environment on the biosynthesis of GTP?

- 2.1.1.1.3.2.1.1.4  
What is the effect of the space environment on the biosynthesis of other nucleotides?
- 2.1.1.1.3.2.1.2  
What is the effect of the space environment on the biosynthesis of DNA?
- 2.1.1.1.3.2.1.3.1  
What is the effect of the space environment on the biosynthesis of messenger RNA?
- 2.1.1.1.3.2.1.3.2  
What is the effect of the space environment on the biosynthesis of transfer RNA?
- 2.1.1.1.3.2.1.3.3  
What is the effect of the space environment on the biosynthesis of ribosomal RNA?
- 2.1.1.1.3.2.1.3.4  
What is the effect of the space environment on the biosynthesis of other RNAs?
- 2.1.1.1.3.3.1  
What is the effect of the space environment on the biosynthesis of coenzyme-A?
- 2.1.1.1.3.3.2  
What is the effect of the space environment on the biosynthesis of flavins?
- 2.1.1.1.3.3.3  
What is the effect of the space environment on the biosynthesis of biotin?
- 2.1.1.1.3.3.4  
What is the effect of the space environment on the biosynthesis of nicotinic acid?
- 2.1.1.1.3.3.5  
What is the effect of the space environment on the biosynthesis of folic acid?
- 2.1.1.1.3.3.6  
What is the effect of the space environment on the biosynthesis of cobamide coenzyme?
- 2.1.1.1.3.3.7  
What is the effect of the space environment on the biosynthesis of thiamine cocarboxylase?



- 2.1.1.1.3.3.8  
What is the effect of the space environment on the biosynthesis of other enzyme cofactors?
- 2.1.1.2.1.1.1  
What is the effect of the space environment on the metabolic control functions of auxins?
- 2.1.1.2.1.1.2  
What is the effect of the space environment on the metabolic control functions of kinetins?
- 2.1.1.2.1.1.3  
What is the effect of the space environment on the metabolic control functions of gibberellins?
- 2.1.1.3.1.1.1  
What is the effect of the space environment on the breakdown of ATP?
- 2.1.1.3.1.1.2  
What is the effect of the space environment on the breakdown of UTP?
- 2.1.1.3.1.1.3  
What is the effect of the space environment on the breakdown of ITP?
- 2.1.1.3.1.1.4  
What is the effect of the space environment on the breakdown of GTP?
- 2.1.1.3.1.2.1  
What is the effect of the space environment on the breakdown of adenosine?
- 2.1.1.3.1.2.2  
What is the effect of the space environment on the breakdown of cytidine?
- 2.1.1.3.1.2.3  
What is the effect of the space environment on the breakdown of inosine?
- 2.1.1.3.1.2.4  
What is the effect of the space environment on the breakdown of guanosine?
- 2.1.1.3.1.3.1.1  
What is the effect of the space environment on the breakdown of adenine?

2. 1. 1. 3. 1. 3. 1. 2

What is the effect of the space environment on the breakdown of hypoxanthine?

2. 1. 1. 3. 1. 3. 1. 3

What is the effect of the space environment on the breakdown of xanthine?

2. 1. 1. 3. 1. 3. 1. 4

What is the effect of the space environment on the breakdown of guanine?

2. 1. 1. 3. 1. 3. 2. 1

What is the effect of the space environment on the breakdown of uracil?

2. 1. 1. 3. 1. 3. 2. 2

What is the effect of the space environment on the breakdown of cytosine?

2. 1. 1. 3. 1. 3. 2. 3

What is the effect of the space environment on the breakdown of thymine?

2. 1. 1. 3. 1. 4. 1

What is the effect of the space environment on the breakdown of ribose?

2. 1. 1. 3. 1. 4. 2

What is the effect of the space environment on the breakdown of deoxyribose?

2. 1. 1. 3. 2. 1

What is the effect of the space environment on glycogenic processes?

2. 1. 1. 3. 2. 2

What is the effect of the space environment on amino acid pools?

2. 1. 1. 3. 2. 3

What is the effect of the space environment on ketogenic processes?

2. 1. 1. 3. 3. 1. 1

What is the effect of the space environment on beta-oxidation of fatty acids?

2. 1. 1. 3. 3. 1. 2

What is the effect of the space environment on omega-oxidation of fatty acids?

- 2. 1. 1. 3. 3. 2  
What is the effect of the space environment on the catabolism of triglycerides?
- 2. 1. 1. 3. 4. 1. 1  
What is the effect of the space environment on carbohydrate catabolism through the pentose phosphate shunt?
- 2. 1. 1. 3. 4. 1. 2  
What is the effect of the space environment on carbohydrate catabolism through the TCA cycle?
- 2. 1. 1. 3. 4. 2. 1  
What is the effect of the space environment on carbohydrate catabolism through glycolytic mechanisms?
- 2. 1. 1. 3. 4. 2. 2  
What is the effect of the space environment on carbohydrate catabolism through nonglycolytic mechanisms?
- 2. 1. 2. 1. 1. 1. 1  
What is the effect of the space environment on the reaction mediated by the enzyme, pyruvic oxidase?
- 2. 1. 2. 1. 1. 1. 2  
What is the effect of the space environment on the reaction mediated by the isocitric enzyme?
- 2. 1. 2. 1. 1. 1. 3  
What is the effect of the space environment on the reaction mediated by the enzyme, alpha ketoglutarate oxidase?
- 2. 1. 2. 1. 1. 1. 4  
What is the effect of the space environment on the reaction mediated by the enzyme, succinyl thiokinase?
- 2. 1. 2. 1. 1. 1. 5  
What is the effect of the space environment on the reaction mediated by the enzyme, succinic dehydrogenase?
- 2. 1. 2. 1. 1. 1. 6  
What is the effect of the space environment on the reaction mediated by the enzyme, malic dehydrogenase?
- 2. 1. 2. 1. 1. 2. 1  
What is the effect of the space environment on the formation of ATP at the NAD/FAD crossover point?
- 2. 1. 2. 1. 1. 2. 2  
What is the effect of the space environment on the formation of ATP at The FAD/cytochrome C crossover point?

2. 1. 2. 1. 1. 2. 3

What is the effect of the space environment on the formation of ATP at the cytochrome C/cytochrome oxidase crossover point?

2. 1. 2. 1. 1. 3. 1

What is the effect of the space environment on the reactions mediated by the enzyme, glucose-6-phosphate dehydrogenase?

2. 1. 2. 1. 1. 3. 2

What is the effect of the space environment on the reactions mediated by the enzyme, 6-phospho gluconic acid dehydrogenase?

2. 1. 2. 1. 1. 4

What is the effect of the space environment on the reactions mediated by the enzyme, acyl dehydrogenase?

2. 1. 2. 1. 1. 5

What is the effect of the space environment on the reactions mediated by the enzyme, hydroxyacyl dehydrogenase?

2. 1. 2. 1. 1. 5. 1

What is the effect of the space environment on the reactions mediated by glutamic acid dehydrogenase?

2. 1. 2. 1. 1. 6. 1

What is the effect of the space environment on the reactions mediated by the transaminases?

2. 1. 2. 1. 2. 1. 1

What is the effect of the space environment on the glycolytic reaction mediated by the enzyme, phosphoglyceraldehyde dehydrogenase?

2. 1. 2. 1. 2. 1. 2

What is the effect of the space environment on the glycolytic reaction mediated by the enzyme, phosphoglycerol kinase?

2. 1. 2. 1. 2. 1. 3

What is the effect of the space environment on the glycolytic reaction mediated by the enzyme, pyruvic oxidase?

2. 1. 2. 2. 1. 1

What is the effect of the space environment on the reaction mediated by enzyme, transhydrogenase (ferridoxin/NAD(P) reductase)?

2. 1. 3. 1. 6

What is the effect of the space environment on the possibility of an interaction between two or more of the tropic responses?

2. 1. 3. 1. 7

What is the effect of the space environment on any existing correlations between the tropic responses and metabolic or energetic reactions?

2. 1. 3. 2. 1. 3

What is the effect of the space environment on circadian rhythms, as manifested by flower and leaf movements?

2. 1. 3. 2. 1. 4

What is the effect of the space environment on circadian rhythms, as manifested by organic acid metabolism in succulents?

2. 1. 3. 2. 1. 5

What is the effect of the space environment on circadian rhythms, as manifested by phototaxis?

2. 1. 3. 2. 1. 6

What is the effect of the space environment on circadian rhythms, as manifested by rate of photosynthesis?

2.1.3.2.1.8

What is the effect of the space environment on circadian rhythms, as manifested by cell division?

2.1.3.2.1.9

What is the effect of the space environment on circadian rhythms, as manifested by root exudation?

2.1.3.2.6.8

What is the effect of the space environment on rhythms that are independent of environmental periodicities, as exemplified by glycolytic enzyme oscillations?

2.1.3.2.7.2.1

What is the effect of the space environment on the influence of metabolic or energetic reactions on rhythmic processes as the result of nuclear control?

2.1.3.2.7.1.2

What is the effect of the space environment on the influence of metabolic or energetic reactions on rhythmic processes as the result of oscillations in membrane properties?

2.1.3.2.7.1.4

What is the effect of the space environment on the influence of metabolic or energetic reactions on rhythmic processes as the result of the indicator process?

2.1.3.2.7.1.5

What is the effect of the space environment on the influence of metabolic or energetic reactions on rhythmic processes as the result of the basic (time-reference) oscillator?

2.1.4.1.1.2.1

What is the effect of the space environment on plant sexual reproduction by isogametes?

2.1.4.1.1.2.2.1

What is the effect of the space environment on heterogametic plant reproduction found in the antheridium?

2.1.4.1.1.2.2.2

What is the effect of the space environment on heterogametic plant reproduction found in the oogonium?

2.1.4.2.1.1

What is the effect of the space environment on the frequency of lethal mutations?

2.1.4.2.1.2

What is the effect of the space environment on the frequency of conditional-lethal mutations?

2.1.4.2.1.3

What is the effect of the space environment on the frequency of nonlethal mutations?

2.1.4.2.1.3.1

What is the effect of the space environment on the frequency of nonlethal mutations, as manifested by structural abnormalities?

2.1.4.2.1.3.2

What is the effect of the space environment on the frequency of nonlethal mutations, as manifested by biochemical abnormalities?

2. 1. 4. 2. 1. 3. 3

What is the effect of the space environment on the frequency of nonlethal mutations, as manifested by chromosomal abnormalities?

2. 1. 5. 1. 2. 2. 3. 1

What is the effect of the space environment on the response of structural support to external stress?

2. 1. 5. 1. 2. 2. 3. 2

What is the effect of the space environment on the response of structural support to internal stress?

2. 1. 5. 1. 2. 2. 3. 3

What is the effect of the space environment on the response of structural support to plant shape?

2. 1. 5. 1. 3. 1. 1

What is the effect of the space environment on the transport of organic nutrients?

2. 1. 5. 1. 3. 1. 2

What is the effect of the space environment on the transport of inorganic nutrients?

2. 1. 5. 1. 5. 2

What is the effect of the space environment on life span?

**EARTH ORBITAL EXPERIMENT PROGRAM  
AND REQUIREMENTS STUDY**

**SPACE BIOLOGY**

**RESEARCH CLUSTER-2-PL-3  
ADVANCED INVESTIGATIONS OF BIOLOGICAL PROCESSES,  
USING PLANTS**

*C-2-133*



ADVANCED INVESTIGATIONS OF BIOLOGICAL PROCESSES,  
USING PLANTS

Critical Issues Addressed by Research Cluster

2-PL-3

2.1.1.1.1.1.1

What is the effect of the space environment on the biosynthesis of starch?

2.1.1.1.1.1.2

What is the effect of the space environment on the biosynthesis of fructosans?

2.1.1.1.1.1.3

What is the effect of the space environment on the biosynthesis of mannans?

2.1.1.1.1.1.5

What is the effect of the space environment on the biosynthesis of dextran?

2.1.1.1.1.1.6

What is the effect of the space environment on the biosynthesis of inulin?

2.1.1.1.1.3.1

What is the effect of the space environment on the biosynthesis of acetyl coenzyme-A?

2.1.1.1.2.1.2

What is the effect of the space environment on the biosynthesis of cellulose?

2.1.1.1.2.1.3

What is the effect of the space environment on the biosynthesis of xylan?

2.1.1.1.2.1.4

What is the effect of the space environment on the biosynthesis of arabinose?

2.1.1.1.2.1.5

What is the effect of the space environment on the biosynthesis of mannose?

2.1.1.1.2.1.6

What is the effect of the space environment on the biosynthesis of lignin?

2.1.1.1.2.1.7

What is the effect of the space environment on the biosynthesis of other polysaccharides?

2.1.1.1.2.2.1.1

What is the effect of the space environment on the anabolism of calcium?

2.1.1.1.2.2.2.1

What is the effect of the space environment on the anabolism of sodium?

2.1.1.1.2.2.2.2

What is the effect of the space environment on the anabolism of potassium?

2.1.1.1.2.2.2.3

What is the effect of the space environment on the anabolism of chloride?

2.1.1.1.2.2.2.4

What is the effect of the space environment on the anabolism of other nonskeletal minerals?

2.1.1.1.3.1.1.1

What is the effect of the space environment on the biosynthesis of auxins?

2.1.1.1.3.1.1.2

What is the effect of the space environment on the biosynthesis of kinetins?

2.1.1.1.3.1.1.3

What is the effect of the space environment on the biosynthesis of gibberellins?

2.1.1.1.3.2.1.1.1

What is the effect of the space environment on the biosynthesis of ATP?

2.1.1.1.3.2.1.1.2

What is the effect of the space environment on the biosynthesis of UTP?

2.1.1.1.3.2.1.1.3

What is the effect of the space environment on the biosynthesis of GTP?

- 2.1.1.1.3.2.1.1.4  
What is the effect of the space environment on the biosynthesis of other nucleotides?
- 2.1.1.1.3.2.1.2  
What is the effect of the space environment on the biosynthesis of DNA?
- 2.1.1.1.3.2.1.3.1  
What is the effect of the space environment on the biosynthesis of messenger RNA?
- 2.1.1.1.3.2.1.3.2  
What is the effect of the space environment on the biosynthesis of transfer RNA?
- 2.1.1.1.3.2.1.3.3  
What is the effect of the space environment on the biosynthesis of ribosomal RNA?
- 2.1.1.1.3.2.1.3.4  
What is the effect of the space environment on the biosynthesis of other RNAs?
- 2.1.1.1.3.2.2  
What is the effect of the space environment on the biosynthesis of histones?
- 2.1.1.1.3.3.1  
What is the effect of the space environment on the biosynthesis of coenzyme-A?
- 2.1.1.1.3.3.2  
What is the effect of the space environment on the biosynthesis of flavins?
- 2.1.1.1.3.3.3  
What is the effect of the space environment on the biosynthesis of biotin?
- 2.1.1.1.3.3.4  
What is the effect of the space environment on the biosynthesis of nicotinic acid?
- 2.1.1.1.3.3.5  
What is the effect of the space environment on the biosynthesis of folic acid?
- 2.1.1.1.3.3.6  
What is the effect of the space environment on the biosynthesis of cobamide coenzyme?

- 2.1.1.1.3.3.7  
What is the effect of the space environment on the biosynthesis of thiamine cocarboxylase?
- 2.1.1.1.3.3.8  
What is the effect of the space environment on the biosynthesis of other enzyme cofactors?
- 2.1.1.2.1.1.1  
What is the effect of the space environment on the metabolic control functions of auxins?
- 2.1.1.2.1.1.2  
What is the effect of the space environment on the metabolic control functions of kinetins?
- 2.1.1.2.1.1.3  
What is the effect of the space environment on the metabolic control functions of gibberellins?
- 2.1.1.3.1.1.1  
What is the effect of the space environment on the breakdown of ATP?
- 2.1.1.3.1.1.2  
What is the effect of the space environment on the breakdown of UTP?
- 2.1.1.3.1.1.3  
What is the effect of the space environment on the breakdown of ITP?
- 2.1.1.3.1.1.4  
What is the effect of the space environment on the breakdown of GTP?
- 2.1.1.3.1.2.1  
What is the effect of the space environment on the breakdown of adenosine?
- 2.1.1.3.1.2.2  
What is the effect of the space environment on the breakdown of cytidine?
- 2.1.1.3.1.2.3  
What is the effect of the space environment on the breakdown of inosine?
- 2.1.1.3.1.2.4  
What is the effect of the space environment on the breakdown of guanosine?

- 2.1.1.3.1.3.1.1  
What is the effect of the space environment on the breakdown of adenine?
- 2.1.1.3.1.3.1.2  
What is the effect of the space environment on the breakdown of hypoxanthine?
- 2.1.1.3.1.3.1.3  
What is the effect of the space environment on the breakdown of xanthine?
- 2.1.1.3.1.3.1.4  
What is the effect of the space environment on the breakdown of guanine?
- 2.1.1.3.1.3.2.1  
What is the effect of the space environment on the breakdown of uracil?
- 2.1.1.3.1.3.2.2  
What is the effect of the space environment on the breakdown of cytosine?
- 2.1.1.3.1.3.2.3  
What is the effect of the space environment on the breakdown of thymine?
- 2.1.1.3.1.4.1  
What is the effect of the space environment on the breakdown of ribose?
- 2.1.1.3.1.4.2  
What is the effect of the space environment on the breakdown of deoxyribose?
- 2.1.1.3.2.1  
What is the effect of the space environment on the breakdown of glycolytic processes?
- 2.1.1.3.2.2  
What is the effect of the space environment on the breakdown of amino acid pools?
- 2.1.1.3.2.3  
What is the effect of the space environment on the breakdown of ketogenic processes?
- 2.1.1.3.3.1.1  
What is the effect of the space environment on the breakdown of beta-oxidation of fatty acids?

2.1.1.3.3.1.2

What is the effect of the space environment on omega-oxidation of fatty acids?

2.1.1.3.3.2

What is the effect of the space environment on the catabolism of triglycerides?

2.1.1.3.4.1.1

What is the effect of the space environment on carbohydrate catabolism through the pentose phosphate shunt?

2.1.1.3.4.1.2

What is the effect of the space environment on carbohydrate catabolism through the TCA cycle?

2.1.1.3.4.2.1

What is the effect of the space environment on carbohydrate catabolism through glycolytic mechanisms?

2.1.1.3.4.2.2

What is the effect of the space environment on carbohydrate catabolism through nonglycolytic mechanisms?

2.1.2.1.1.1.1

What is the effect of the space environment on the reaction mediated by the enzyme, pyruvic oxidase?

2.1.2.1.1.1.2

What is the effect of the space environment on the reaction mediated by the isocitric enzyme?

2.1.2.1.1.1.3

What is the effect of the space environment on the reaction mediated by the enzyme, alpha ketoglutarate oxidase?

2.1.2.1.1.1.4

What is the effect of the space environment on the reaction mediated by the enzyme, succinyl thiokinase?

2.1.2.1.1.1.5

What is the effect of the space environment on the reaction mediated by the enzyme, succinic dehydrogenase?

2.1.2.1.1.1.6

What is the effect of the space environment on the reaction mediated by the enzyme, malic dehydrogenase?

2.1.2.1.1.2.1

What is the effect of the space environment on the formation of ATP at the NAD/FAD crossover point?

2.1.2.1.1.2.2

What is the effect of the space environment on the formation of ATP at the FAD/cytochrome C crossover point?

2.1.2.1.1.2.3

What is the effect of the space environment on the formation of ATP at the cytochrome C/cytochrome oxidase crossover point?

2.1.2.1.1.3.1

What is the effect of the space environment on the reaction mediated by the enzyme, glucose-6-phosphate dehydrogenase?

2.1.2.1.1.3.2

What is the effect of the space environment on the reactions mediated by the enzyme, 6-phospho gluconic acid dehydrogenase?

2.1.2.1.1.4.1

What is the effect of the space environment on the reactions mediated by the enzyme, acyl dehydrogenase?

2.1.2.1.1.4.2

What is the effect of the space environment on the reactions mediated by the enzyme, hydroxyacyl dehydrogenase?

2.1.2.1.1.5.1

What is the effect of the space environment on the reactions mediated by glutamic acid dehydrogenase?

2.1.2.1.1.5.2

What is the effect of the space environment on the reactions mediated by D-amino acid oxidase?

2.1.2.1.1.6.1

What is the effect of the space environment on the reactions mediated by the transaminases?

2.1.2.1.2.1.1

What is the effect of the space environment on the glycolytic reaction mediated by the enzyme, phospho-glyceraldehyde dehydrogenase?

2.1.2.1.2.1.2

What is the effect of the space environment on the glycolitic reaction mediated by the enzyme, phosphoglyceryl kinase?

2.1.2.1.2.1.3

What is the effect of the space environment on the glycolitic reaction mediated by the enzyme, pyruvic oxidase?

2.1.3.1.6

What is the effect of the space environment on the possibility of an interaction between two or more of the tropic responses?

2.1.3.1.7

What is the effect of the space environment on any existing correlations between the tropic responses and metabolic or energetic reactions?

2.1.3.2.1.3

What is the effect of the space environment on circadian rhythms, as manifested by flow and leaf movements?

2.1.3.2.1.4

What is the effect of the space environment on circadian rhythms, as manifested by organic acid metabolism in succulents?

2.1.3.2.1.5

What is the effect of the space environment on circadian rhythms, as manifested by phototaxis?

2.1.3.2.1.6

What is the effect of the space environment on circadian rhythms, as manifested by rate of photosynthesis?

2.1.3.2.1.8

What is the effect of the space environment on circadian rhythms, as manifested by cell division?

2.1.3.2.1.9

What is the effect of the space environment on circadian rhythms, as manifested by root exudation?



2.1.3.2.7.2.1

What is the effect of the space environment on the influence of metabolic or energetic reactions on rhythmic processes that results from nuclear control?

2.1.3.2.7.2.2

What is the effect of the space environment on the influence of metabolic or energetic reactions on rhythmic processes that results from oscillations in membrane properties?

2.1.3.2.7.2.4

What is the effect of the space environment on the influence of metabolic or energetic reactions on rhythmic processes that results from the indicator process?

2.1.3.2.7.2.5

What is the effect of the space environment on the influence of metabolic or energetic reactions on rhythmic processes that results from the basic (time-reference) oscillator?

2.1.4.1.1.2.1

What is the effect of the space environment on plant sexual reproduction by isogametes?

2.1.4.1.1.2.2.1

What is the effect of the space environment on heterogametic plant reproduction found in the antheridium?

2.1.4.1.1.2.2.2

What is the effect of the space environment on heterogametic plant reproduction found in the oogonium?

2.1.4.2.1.1

What is the effect of the space environment on the frequency of lethal mutations?

2.1.4.2.1.2

What is the effect of the space environment on the frequency of conditional-lethal mutations?

2.1.4.2.1.3

What is the effect of the space environment on the frequency of nonlethal mutations?

2.1.4.2.1.3.1

What is the effect of the space environment on the frequency of nonlethal mutations, as manifested by structural abnormalities?

2.1.4.2.1.3.2

What is the effect of the space environment on the frequency of nonlethal mutations, as manifested by biochemical abnormalities?

2.1.4.2.1.3.3

What is the effect of the space environment on the frequency of nonlethal mutations, as manifested by chromosomal abnormalities?

2.1.5.1.2.2.3.1

What is the effect of the space environment on the response of structural support to external stress?

2.1.5.1.2.2.3.2

What is the effect of the space environment on the response of structural support to internal stress?

2.1.5.1.2.2.3.3

What is the effect of the space environment on the response of structural support to plant shape?

2.1.5.1.3.1.1

What is the effect of the space environment on the transport of organic nutrients?

2.1.5.1.3.1.2

What is the effect of the space environment on the transport of inorganic nutrients?

2.1.5.1.5.2

What is the effect of the space environment on life span?

TABLE 1. LEGEND OF CODES USED IN CREW ACTIVITY MATRICES

Table 1 is an explanation of the codes used in the following matrices. The matrices summarize the inflight crew tasks required to conduct and support the research identified in the synopsis.

TYPE OF ACTIVITY

- |   |   |
|---|---|
| 0 - Not covered below                   | 5 - Conduct of experiment   |
| 1 - Experimental subject                | 6 - Evaluate intermediate results   |
| 2 - Spacecraft operations               | 7 - Direct observation of phenomena                                       |
| 3 - Preexperiment equipment preparation | 8 - Data handling   |
| 4 - Maintenance of equipment            | 9 - Communications; initiate and receive transmissions (telemetry, voice) |

CREW SKILL

- |                               |                      |
|-------------------------------|----------------------|
| 0 - No special skill required | 12 - Meteorology     |
| 1 - Medicine                  | 13 - Geography       |
| 2 - Biology                   | 14 - Cartography     |
| 3 - Physiology                | 15 - Hydrology       |
| 4 - Psychology                | 16 - Navigation      |
| 5 - Engineering               | 17 - Communications  |
| 6 - Astronomy                 | 18 - Radiology       |
| 7 - Physics                   | 19 - Instrumentation |
| 8 - Oceanography              | 20 - Photography     |
| 9 - Forestry                  | 21 - Astronaut       |
| 10 - Agriculture              | 22 - Other           |
| 11 - Geology                  |                      |

Each code includes the first one or two digits describing the discipline and a second code letter describing level of skill: A for highest skill level (requires professional training with degree or advanced degree in discipline such as M. D.); B for semiprofessional, the traditional technician level requiring several years of training; C for technician level which requires some special training.

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RESEARCH CLUSTER  
NO. 2-PL-1

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CREW ACTIVITY MATRIX (Page 1 of 4)

RESEARCH CLUSTER NO.	TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE	CREW SKILL	FREQUENCY	ACCUMULATED TASK TIME (MIN)	NO. OF CREWMEN	START	DURATION	TASK CONCURRENCY
2-PL-2 (a)	Investigation of Plant Minerals and Control Mechanisms by Radioactivity									'78		
(p. 1 of 4)	(1) Obtain plant tissue sample	Dissecting microscope and micro-manipulator	3		X	2b	Once Per Week	90	1	"	60 Days	
	(2) Homogenize Tissue	Homogenizer	5			2b	"	90	1	"	"	
	(3) Centrifuge	Laboratory Centrifuge	5			2c	"	20	1	"	"	
	(4) Separate components by partition chromatography	Partition Chromatograph	5			2a	"	120	1	"	"	
	(5) Place in counting jar with phosphor	Radiation Detector	5		X	2b	"	60	1	"	"	
	(6) Turn on instrument	"	5		X	2c	"	5	1	"	"	
	(7) Retrieve and store print-out tape	"	8		X	2c	"	15	1	"	"	
	(8) Clean-up equipment	_____	3		X	2c	"	30	1	"	"	
(b)	Investigation of Plant Respiration and Photosynthetic Activity.									'76		
	(1) Setup and calibrate mass spectrometer	Mass Spectrometer	3		X	2c	Once Per Week	15	1	"	60 Days	
	(2) Separate plant into components	Dissecting microscope and micromanipulator.	3		X	2b	"	20	1	"	"	
	(3) Obtain suitable derivatives	Reagents	5		X	2b	"	60	1	"	"	
	(4) Introduce sample into spectrometer and actuate	Mass Spectrometer	5		X	2a	"	60	1	"	"	
	(5) Obtain chart from recording oscillograph, examine and store	Recording Oscillograph	8		X	2b	"	30	1	"	"	
	(6) Reduce data and perform preliminary analysis.	_____	8		X	2a	"	180	1	"	"	
	(7) Clean up equipment	_____	3		X	2c	"	30	1	"	"	
(c)	Investigation of Metabolic Pathways									Post '80		
	(1) Obtain plant tissue sample	Dissecting Microscope & Micromanipulator	3		X	2b	Once Per Week	90	1	"	60 Days	
	(2) Homogenize tissue sample	Homogenizer	5			2b	"	90	1	"	"	
	(3) Centrifuge at 0-4°C	Refrigerated Centrifuge	5			2b	"	60	1	"	"	
	(4) Prepare reagents	Chemical Reagents	3		X	2b	"	120	1	"	"	
	(5) Add aliquot of centrifugate to reagent	_____	5		X	2b	"	30	1	"	"	

RESEARCH CLUSTER NO.	TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLU- SIVE	CREW SKILL	ACCUMULATED		NO. OF CREWMEN	START	DURA- TION	TASK CONCURRENCY
							FREQUENCY	TASK TIME (MIN)				
2-PL-2 (c)	(6) Incubate as necessary	Incubator	5			2b	Once Per Week	60	1	Post '80	60 Days	
(p. 2 of 4)	(7) Transfer to cuvette	_____	5		X	2b	"	20	1	"	"	
	(8) Place in spectrophotometer	Spectrophotometer	5		X	2c	"	30	1	"	"	
	(9) Select wavelength	"	5		X	2b	"	12	1	"	"	
	(10) Select recorder chart speed	"	5		X	2b	"	6	1	"	"	
	(11) Actuate spectrophotometer	"	5		X	2b	"	30	1	"	"	
	(12) Obtain chart from recorder, examine, and store.	"	8		X	2a	"	60	1	"	"	
	(13) Reduce data and perform preliminary analysis	_____	8		X	2a	"	180	1	"	"	
	(14) Cleanup equipment	_____	3		X	2c	"	30	1	"	"	
(d)	Examination of sub-cellular Organelles and chemical abnormalities.									'78		
	(1) Obtain desired tissue	Dissecting microscope & Micromanipulator	3		X	2b	Once Per Week	90	1	"	60 Days	
	(2) Prepare tissue for paraffin infiltration	Chemical Reagents	5		X	2b	"	60	1	"	"	
	(3) Imbed tissue in paraffin	Paraffin Oven	5			2b	"	180	1	"	"	
	(4) Set program on tissue processor	Tissue Processor	5		X	2b	"	60	1	"	"	
	(5) Sharpen microtome blades	Microtome	5		X	2b	"	120	1	"	"	
	(6) Adjust slice thickness on microtome	Microtome	5		X	2b	"	30	1	"	"	
	(7) Actuate microtome	Microtome	5			2c	"	12	1	"	"	
	(8) Select section from tissue ribbon	_____	5		X	2b	"	60	1	"	"	
	(9) Place section on slide	Microscope Slides	5		X	2b	"	60	1	"	"	
	(10) Set program on staining processor	Staining Processor	5		X	2b	"	30	1	"	"	
	(11) Actuate program	"	5		X	2b	"	12	1	"	"	
	(12) Add cover slip and label to slide	_____	5		X	2b	"	30	1	"	"	
	(13) Examine under microscope	Compound Microscope	5		X	2a	"	90	1	"	"	
	(14) Select area of interest	"	5		X	2a	"	90	1	"	"	
	(15) Adjust camera optics	Microscope Camera	5		X	2b	"	10	1	"	"	
	(16) Photograph	"	5		X	2b	"	6	1	"	"	

RESEARCH CLUSTER NO.	TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLU- SIVE	CREW SKILL	ACCUMULATED		NO. OF CREWMEN	START	DURA- TION	TASK CONCURRENCY
							FREQUENCY	TASK TIME (MIN)				
2-PL-2 (d) (p. 3 of 4)	(17) Log entry	Data Sheets	6		X	2b	Once Per Week	6	1	'78	60 Days	
	(18) Process film	Film Processor	8		X	2c	"	36	1	"	"	
	(19) Examine and store photomicrograph	_____	8		X	2a	"	20	1	"	"	
(e)	Investigation of Plant Lipid Catabolism									Post '80		
	(1) Obtain plant tissue sample	Dissecting Microscope & Micromanipulator	3		X	2b	Once Per Week	90	1	"	60 Days	
	(2) Homogenize tissue	Homogenizer	5			2b	"	90	1	"	"	
	(3) Dry homogenate	Drying Oven	5			2b	"	180	1	"	"	
	(4) Extract with solvent	Chem. Reagents	5		X	2b	"	120	1	"	"	
	(5) Wash impurities from solvent	_____	5		X	2b	"	60	1	"	"	
	(6) Add internal standard	_____	5		X	2b	"	30	1	"	"	
	(7) Adjust volume	_____	5		X	2b	"	30	1	"	"	
	(8) Adjust chromatograph gas flow	Gas Chromatograph	5		X	2a	"	60	1	"	"	
	(9) Introduce sample into chromatograph	"	5		X	2a	"	120	1	"	"	
	(10) Actuate chromatograph operation	"	5		X	2a	"	10	1	"	"	
	(11) Obtain chart from recorder	"	8		X	2b	"	30	1	"	"	
	(12) Reduce data and perform preliminary analysis	_____	8		X	2a	"	180	1	"	"	
(f)	(13) Store records and clean-up equipment	_____	3		X	2c	"	30	1	"	"	
	Investigation of Plant Protein Catabolism									Post '80		
	(1) Obtain plant tissue sample	Dissecting microscope & Micromanipulator	3		X	2b	Once Per Week	90	1	"	60 Days	
	(2) Homogenize tissue	Homogenizer	5			2b	"	90	1	"	"	
	(3) Dry homogenate	Drying Oven	5			2b	"	180	1	"	"	
	(4) Dissolve in appropriate solvent	Chem Reagents	5		X	2b	"	60	1	"	"	
	(5) Add solvent to column of amino acid analyzer	Amino Acid Analyzer	5		X	2a	"	120	1	"	"	
	(6) Adjust analyzer flow rate	"	5		X	2a	"	30	1	"	"	
	(7) Actuate analyzer operation	"	5		X	2a	"	10	1	"	"	

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RESEARCH CLUSTER  
NO. 2-PL-3

C-2-148.